CONSEIL INTERNATIONAL DES UNIONS SCIENTIFIQUES
INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

UNION GÉODÉSIQUE ET GÉOPHYSIQUE INTERNATIONALE
INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

Bulletin of the International Association of Scientific Hydrology

Bulletin de l'Association Internationale d'Hydrologie Scientifique

N° 19

SEPTEMBRE 1960
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Bulletin paraissant 4 fois par an

Published on behalf of
THE INTERNATIONAL ASSOCIATION OF SCIENTIFIC HYDROLOGY
by
CEUTERICK
66, RUE VITAL DECOSTER
LOUVAIN (Belgium)

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THE EDITOR'S COLUMN
LES PROPOS DE LA REDACTION

1. The Council of the Association in latest meeting, at Helsinki, has kindly eed to the proposal of the Secretary he Association that he should be relieved the editorship of the Bulletin and Mr. ard Tison be entrusted with it.

The new editor applied himself at once his duties and now offers you the first e to be prepared by him.

2. He has noted that in that same mee- of the Council certain steps were taken help him in his task. He has seen with sfaction the arrangements made to secure vider diffusion of the Bulletin, to give ncreased standing by virtue of a regular ply of first-class scientific articles and to rove its budgetary position by getting ers for advertisements in it.

The editor will be pleased to receive each adherent country the name of the vidual charged with attending to these eral matters.

3. The present issue already bears s of such help, which comes parti- arly from our American, Dutch and Italian nds. It is in this way that five articles e reached us from the U.S.A. and that Gherardelli has agreed that the paper ch he had been a little late in sending Helsinki should be published in the letin. We are delighted to reap this harvest ch will provide the Bulletin with a notable elopment of its scientific portion.

4. The attention of the reader is drawn ticularly to the account of the meetings the Arid Zones Committee of Unesco l at Paris in May last, as well as to the ils of the symposium held on this occasion.

1. Le Conseil de l'Association, dans sa dernière réunion à Helsinki, a bien voulu accepter une proposition du Secrétaire de l'Association de le décharger de la Rédaction du Bulletin et d'en charger Monsieur Gérard Tison.

Le nouveau rédacteur s'est mis immédiatement à la besogne et il vous présente aujourd'hui son premier bulletin.

2. La rédaction note également avec satisfaction que lors de la même réunion du Conseil, certaines mesures ont été prises pour l'aider dans sa tâche. Elle voit avec satisfaction les mesures prises pour assurer une diffusion plus large du bulletin, pour lui donner un standing plus élevé en l'alimentant régulièrement en communications scientifiques de premier ordre et pour soulager son budget en lui procurant de la publicité.

La rédaction sera heureuse de recevoir, pour chaque pays adhérent, le nom du responsable chargé de veiller à ces différents points.

3. Le présent document porte déjà la marque de cette aide, venant particulièrement de nos amis américains, hollandais et italiens. C'est ainsi que cinq études nous sont parvenues de U.S.A. et que Monsieur Gherardelli a accepté que son étude qu'il avait envoyée peu tardivement pour Helsinki soit publiée dans le bulletin. Nous nous réjouissons de ces apports qui vont donner au bulletin une partie scientifique spécialement développée.

4. D'autre part, l'attention du lecteur est particulièrement attirée sur un compte-rendu des réunions du Comité des Zones Arides de l'Unesco tenues à Paris en mai dernier, ainsi que sur les indications relatives

The discussions were of prime importance for future activity in the interests of arid zones. The Secretary of your Association wishes to give this Committee all possible support and to ensure a collaboration which cannot but be most useful for both bodies concerned.

5. As an instance of this collaboration there was arranged for Helsinki the symposium on Groundwater Maps and another on Droughts and Low Flows. They achieved a great success. Another symposium is being arranged, on Groundwater Resources in Arid Zones, under the same conditions. The present issue gives the first details of it.

6. In assuming charge of the publication of the Bulletin, the new editor wonders if this is not a somewhat heavy burden for one so young. He has, however, not hesitated to accept it for he knows that he can count on the counsels and support of all those who direct or have directed the Association and of all those others who share in its life.

G. Tison, junr.
Brusselse Steenweg 206
Ledeberg
Belgium.

au Colloque tenu à l'occasion de ces réunic
Ces délibérations sont d'une importance
mordiale pour l'action future en faveur
Zones Arides. Le Secrétaire de votre As
ciation désire apporter à ce Comité tou
soutien possible et assurer une collaborat
qui ne peut être que des plus utiles aux d
organismes.

5. A Helsinki, le colloque sur les Ca
des Eaux Souterraines et celui sur les Séc
resses et Débits de Base furent organisés co
me suite à cette collaboration. Ils connur
un grand succès. Un autre Colloque se prép
sur les Ressources en Eaux Souterraines d
les Zones Arides, dans les mêmes conditio
Le présent bulletin donne les premi
indications à ce sujet.

6. En reprenant la charge de la pu
cation du bulletin, le nouveau rédacteur
demande si elle n'est pas un peu lourde p
sa jeunesse. Il n'a cependant pas hésité
reprendre car il sait pouvoir compter sur
conseils et l'appui de ceux qui dirigent
ont dirigé l'Association et de tous ceux
participent à sa vie.

PARTIE SCIENTIFIQUE
SCIENTIFIC PART

REAL FLOOD-FREQUENCY ANALYSIS IN A HUMID REGION (1)

M.A. BENSON
U.S. Geological Survey Washington 25, D.C.

ract

This study was made to define the relation between floods in a humid region and the ative factors that account for their variability. The study covered the basic relationships een peak discharges and hydrologic factors as well as the practical working methods for ralizing the results on a regional basis. Statistical multiple-correlation techniques were ed to hydrologic data in New England. A field and library investigation of historical flood extended the period of flood knowledge to as much as 300 years. The relation of many graphic and climatic factors to flood peaks was tested. Flood peaks with recurrence vals at 9 levels, from 1.2 to 300 years, were related to 6 independent variables, 3 of h are topographic, 2 climatic, and 1 orographic.

ODUCTION

The investigation described here was made as part of a continuing study to determine the e of variation in flood peaks from place to place and to improve methods of defining l-frequency relations on a generalized basis.

The measuring of discharge at about 7,000 stream-gaging stations in the United States is npling process in both time and space. The 25- or 50-year record of floods that may be able at a station is only a sample in time of the total experience of floods there. The rience at the 7,000 gaging sites comprises only a sample in space of the flood potential e infinite number of possible sites on all the streams in the country.

All the flood data available must be used to describe the variation with time and to analyze auses for the variation with location. The spatial variation in flood experience must be ed to the hydrologic factors that cause the variation. The hydrologic factors may be divided two principal classes — topographic, and climatic. The climatic factors are chiefly those account for the variation in the supply of water causing floods. The topographic factors hose physical characteristics of the drainage basin that affect the pattern of the runoff and e the size of peaks.

1) Publication authorized by Director, U.S. Geological Survey.

CHOICE OF STUDY REGION

The chances of success were considered better if the study were started in some region within which the climatic variations and variations in runoff were not extreme. pointed to a humid region. Other requirements were that the region have fairly long records and be fully mapped. New England seemed to meet the requirements better than other area.

METHODS OF ANALYZING FLOODS

Technical literature on the subject of flood frequency has been concerned mainly the distribution of floods at a single site. This has been a controversial subject, although not the most important part of the general problem of determining flood-frequency relat Defining the frequency curves at individual sites, by whatever means, is only the first pa the job; generalization has not been accomplished until the flood peak data are related to h logic factors.

It is necessary to start, however, by defining the flood-frequency distribution or cur each individual site where flood data are available. There are many theories and many of doing this. The methods may be divided primarily into mathematical and graphical. A dec on procedure had to be made here. It was decided to use graphical methods of producin quency curves at individual stations. The chief reason for this was that basic hydrologic rela ships as yet unknown were being investigated; it was desirable that the results not be aff by any possible bias introduced by assuming a theoretical distribution. It is not yet possit demonstrate *a priori* that floods must conform to some one type of distribution. It is also cult to justify any distribution on empirical grounds, because although it is easy to sh fit between theory and data in the region of the mean, it is hard to do so at the extremes this is the region of interest for floods. Graphical methods may vary slightly with the doing the work, but the results of careful work do not have a built-in bias.

One method currently in use for regionalizing flood frequency is to use an index usually the mean annual peak discharge. All other floods at a station are then expressed ratio to the mean annual flood. The dimensionless ratios are then combined for all sta within a homogeneous area, to obtain a generalized basic flood-frequency relation in of ratio to the mean annual flood. This method places some restriction on the results be it does not allow for the possibility that the ratio of a given flood, say the 10-year floo the mean may not be constant at all stations, but may vary with physical or climatic cond prevailing over each basin. In order to avoid any restrictions on the relations that mig developed, it was considered best to make independent analyses at many different flood l

ANALYTICAL PROCEDURES

The available stream-gaging records in New England were examined and those that too short, too close to another station, or affected excessively by regulation were elimir There still remained 164 stations to use in the analysis. One of the first parts of the stud an investigation of historical flood data in New England, which extended the knowled flood events back between 200 and 300 years.

Maximum annual momentary peak discharges were listed for each station, and were arranged in order of magnitude. Probabilities for each peak were computed as $m/(n$ where m is the rank starting with one as the highest and n is the number of years of re Where the historical study indicated long effective recurrence intervals for some of the major floods, the longer periods of time, rather than the recent periods of record, were to compute their probabilities.

The peaks at each station were plotted on log-probability graph paper, and graphical ency curves were drawn. Each curve was drawn only as high as defined by the data at the on. From the 164 station frequency curves, peak discharges were determined, within the of each curve, at the probabilities corresponding to recurrence intervals of 1.2, 2.33, , 25, 50, 100, 200, and 300 years. Table 1 shows the amount of data at each of the 9 levels.

TABLE 1

NUMBER OF STATIONS DEFINING T-YEAR FLOODS

Recurrence Interval, T, in years	Number of Stations
1.2	164
2.33	164
5	164
10	164
25	154
50	116
100	100
200	68
300	22

At each of these levels, the peak discharges, as dependent variables, were correlated by iple-correlation techniques with many hydrologic variables. These variables were chosen by considering what factors might be expected to have an important effect on peak discharge, by finding means of expressing them either directly or indirectly by some suitable index. following list (table 2) shows the variables investigated.

Some of the variables listed in Table 2 have been described and evaluated for many New and drainage basins by *Langbein* (1947). Other variables, such as indices for the main-nel slope, curvature of the main-channel profile, and the altitude distribution, were devised ie course of this study.

In the first part of the investigation, graphical multiple-correlation techniques were used. ly showed that linear relationships existed between peak discharges and all hydrologic ors when the logarithms of all the data were used. Various indices of each of the factors cted to influence flood were tested for their efficiency in accounting for the variations in s. Drainage-area size, considered and later demonstrated to be of prime importance, was oduced first. Some measure of the main-channel slope was found to be next in importance rainage area. Several methods for expressing main-channel slope were tested and finally nple yet efficient index (Benson, 1959) was devised. This is the slope (in feet per mile) between points along the main channel, one of which is 85 percent, the other 10 percent, of the total n-channel length above the gaging point.

Following main-channel slope, *S*, the percentage of surface area in lakes and ponds, eased by 0.5 percent for linearization), *St*, was found to be a significant variable.

A fourth independent variable found significant was I, the rainfall intensity-frequency nitude (in inches) for a 24-hour duration and a recurrence interval equal to that of the peak harge. These data were obtained by use of U.S. Weather Bureau Technical Paper N° 29, nfall intensity-frequency regime, Part 4 — Northeastern United States, 1959.

Table 2

Independent variables analyzed

1. Drainage-area size

2. Slope
   - Main-channel:
     - Langbein factor
     - Bigwood-Thomas factor
     - Potter factor
     - Logarithmic
     - 85-10% point elevations
   - Tributary channel
   - Average land slope
   - Profile curvature

3. Storage area
   - Lakes, ponds, and swamps
   - Lakes and ponds

4. Stream density

5. Altitude
   - Mean
   - Mean above gage
   - Altitude distribution index

6. Shape and drainage pattern
   - L, $1/W$, L/W, Σal, $(\Sigma \mathrm{al})/A$, L. Log A,
   - Shape classification (1 to 6)

7. Index of available moisture
   - Mean annual precipitation
   - Mean annual runoff
   - Mean March to May precipitation
   - Mean annual runoff/precipitation ratio
   - Mean March to May runoff/precipitation ratio
   - Maximum 24-hour precipitation
   - Rainfall intensity-frequency

8. Temperature
   - Mean January temperature
   - Mean January degrees below freezing

9. Orographic factor

Graphical multiple correlation becomes insensitive after 3 or 4 variables. At this point tiple-correlation equations were computed mathematically at all 9 of the flood levels, values of the flood peaks were computed, by means of the equations, for all stations. ratios of the actual to the computed peaks were averaged at each station, and those r representing error or departures, were then plotted on a map of New England (Fig. 1).

The multiple correlation developed to this point would not be considered satisfa

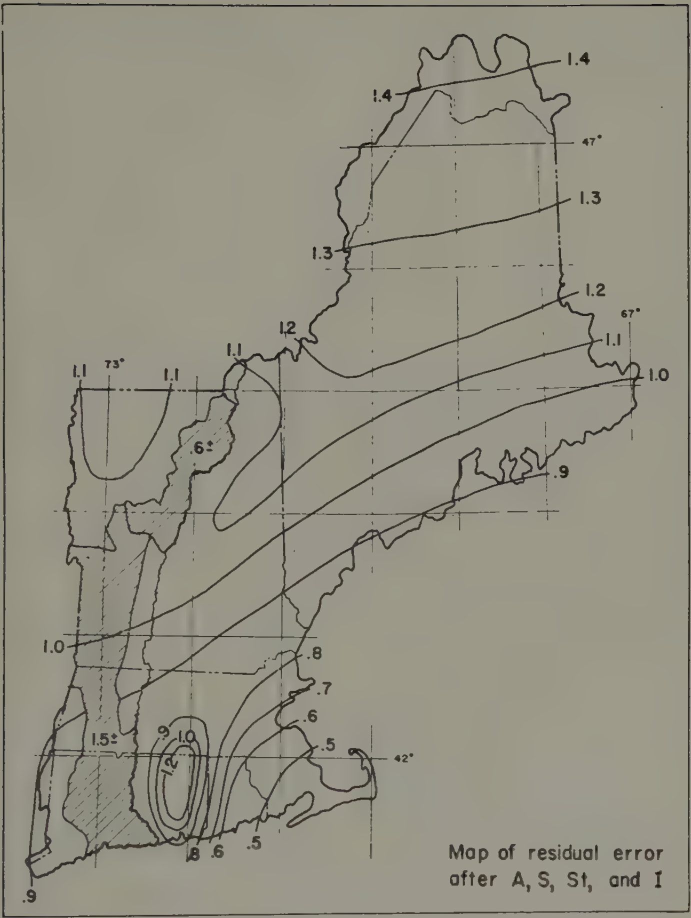

Fig. 1 — Map of residual error after *A*, *S*, *St*, and *I*

less, as a minimum requirement, the errors were found to be randomly distributed. In ure 1 the contours have been drawn to average the departures. They demonstrate a definite ographic pattern. Note that the ratios are high in the north (above 1) and change gradually low values (below 1) in the south. An area along the Connecticut River shows a break in the gular pattern. The general north-to-south variation is consistent with the expected effect one factor not yet included in the correlation — the effect of snowmelt and frozen ground augmenting peak flows. The general pattern of departures is almost duplicated in the map mean January temperature shown in figure 2.

Most annual flood peaks in New England occur in the three-month period from March rough May. The ratio of total runoff over total precipitation in the March-to-May period shown by contours in Figure 3. The north-to-south variation is depicted here also. North the line labelled 1.0, the runoff is higher than the precipitation during these three months, cause of the melting of snow previously accumulated.

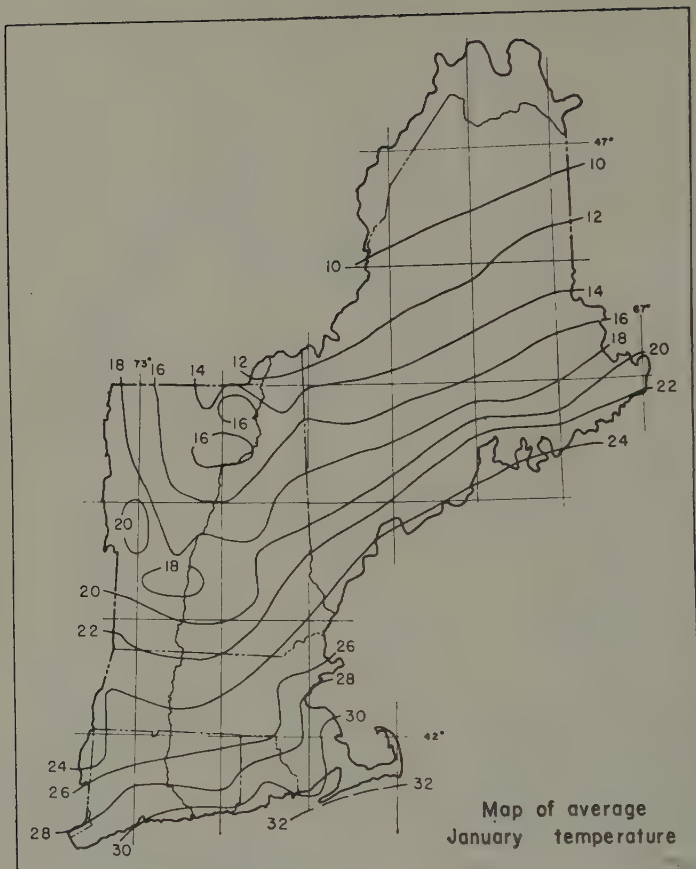

Fig. 2 — Map of mean January temperature

Data on the normal water content of accumulated snow at the time of the spring breaku are lacking, but either January temperature or the 3-month runoff-precipitation ratio may b used as an index of snowmelt. Average January temperature was chosen, and was converte to average degrees below freezing, *t*, (with a minimum value of 1.0). After adding this variab to the regression equations, flood peaks were recomputed and another set of residual erro obtained that were again mapped as shown in figure 4.

Maine is omitted from this map, and the remainder expanded. The introduction of temper ture eliminates the north-to-south variation and gives a random scatter of errors everywhe except along the Connecticut River. Examination of the pattern now defined by the residu errors shows a definite relation to orography. Storm winds come mainly from the east or sout east. The area of depression contours in the north is a basin flanked on the east by the Whi Mountain chain, the highest in New England. West of the northern part of the White Mountair there is a definite rain shadow, perhaps better termed a « peak-discharge shadow ». South about the 43°45′ latitude, the White Mountains become low; the Green Mountains, whi form the western ridge of the Connecticut Valley, are the highest in the east-west direction a

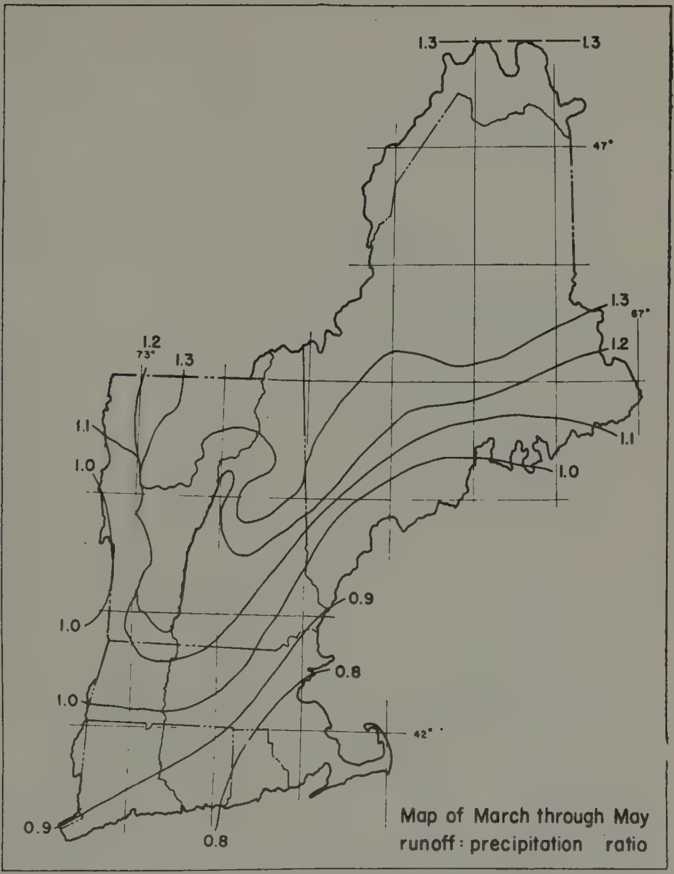

Fig. 3 — Map of runoff/precipitation ratio, March through May

ecome the controlling feature. The residual errors of the individual gaging stations show an crease up the slopes on the east side of the Green Mountains. As we progress southward to estern Massachusetts and to Connecticut, which receive the highest storm rains in New ngland, the mountains have become hills. The first rise in elevation met by the winds from the st causes an increase in peak discharges; proceeding west into the Connecticut Valley, there is a ecrease, then a rise on the other side. Figure 5 shows what happens along the 42° 15′ line; e top line is the ground elevation and the lower line is the pattern of residuals.

The pattern portrayed in figure 4 represents variations in peaks that are unaccounted r by the precipitation and temperature variables already used. Perhaps the precipitation or mperature maps are based on too little data in the mountain areas or perhaps the orographic fect on peaks is too complex to be expressed by one or two simple climatic indices. One prac- cal expedient for expressing the effect of orography would be to use, as an orographic factor, lues based on the contours of figure 4, which are consistently defined by the residuals of flood scharge at each station. The discharges are from entire basins, therefore they represent the tegrated effect of whatever conditions are responsible for the pattern. When an orographic

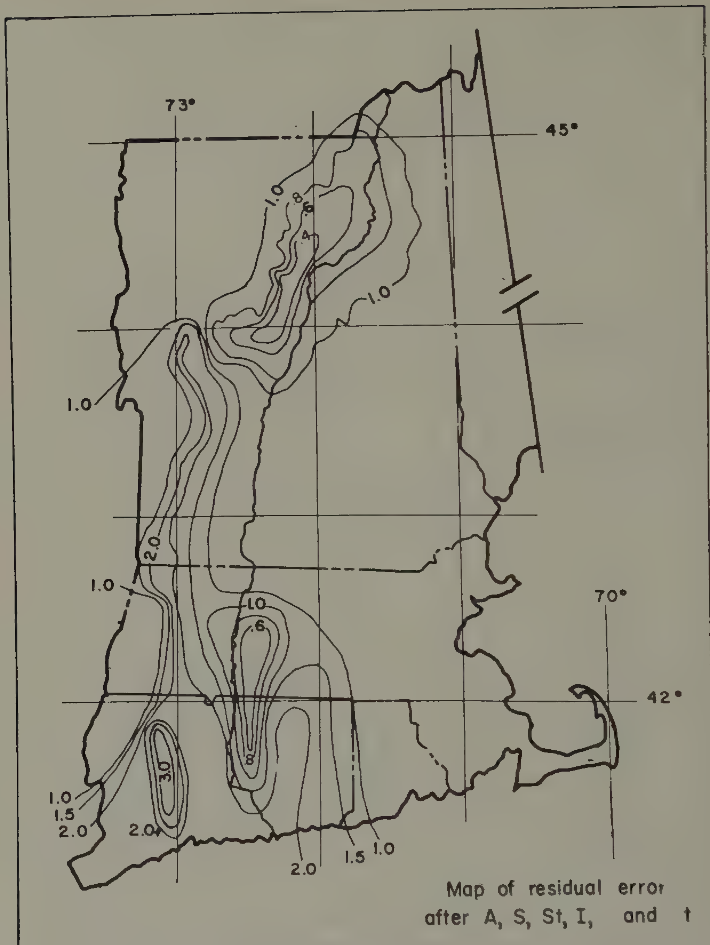

Fig. 4 — Map of residual error after *A*, *S*, *St*, *I*, and *t*

factor, *O*, based on the mapped contours, is introduced into the regression equations, th final residuals are then found to be randomly scattered over all of New England.

It would have been possible to use other variables of those investigated instead of the on finally used. For example, average land slope, stream density, or others might have been use instead of main-channel slope. Each of these is highly correlated with the others. Howeve the main-channel slope proved to be the most efficient of these, i.e., it accounted for a larg part of the variation in peak discharges. After main-channel slope was introduced as a variab the other like variables no longer added anything significant to the correlation.

No basin shape factor could be found that had any significant relation to flood peak despite the fact that reasoning shows that shape must have an effect. Apparently, the bas shape has to a large extent been accounted for once drainage area and slope have been include This is because slope is computed on basis of the length of the main channel — for a given si of drainage area a variation in main-channel length indicates a variation in shape.

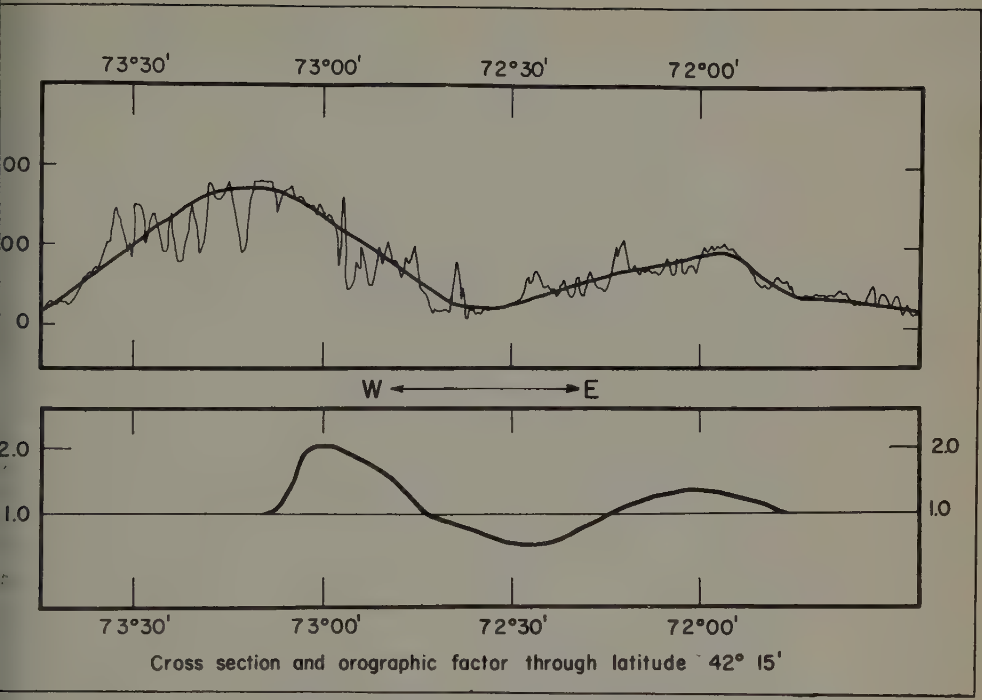

Fig. 5 — Cross section and orographic factor through latitude 42° 15′

ULTS

multiple-correlation equations which have been developed are of the following form :

$$Q_T = a A^b S^c St^d I^e t^f O^g$$

There are six independent variables. The first three — area, main-channel slope, and ace storage — are topographic variables. The next two, precipitation intensity and tempera-, are climatic variables. The last is an orographic factor, a combination of topography climate.

Drainage area is the most important variable. The standard deviation of the original peak harges range between 130 and 190 percent (average of plus and minus deviations) of the n values at each level. The use of drainage area leads to standard errors ranging only from o 70 percent. Slope is highly important and it accounts for a 10 to 20 percent reduction in standard error over that using area alone. Storage further improves the standard error veen 2 and 5 percent. Rainfall intensity is not statistically significant below about 10 years; ve 10 years the improvement in standard error ranges up to 3 percent. Temperature improves standard error between 1 and 4 percent. The orographic factor improves the standard error veen 5 and 20 percent. Although intensity and temperature each improve the overall stan-l error less than 5 percent, they are factors that vary regionally rather than randomly the improvement in standard error does not tell the whole story. For example, the mapped dual error before temperature was introduced (fig. 1) showed errors ranging from plus ercent in northern New England to minus 50 percent in southern New England. These

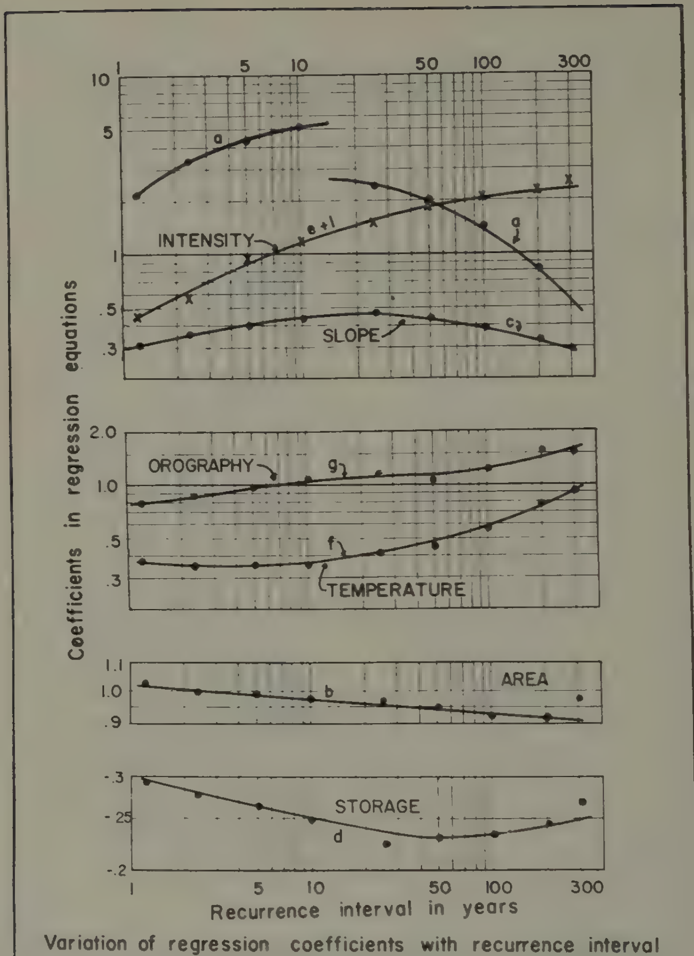

Fig. 6 — Variation in regression coefficients

regional errors were removed by temperature although the average improvement is o
1 to 4 percent.

Figure 6 shows how the exponents in the general equation vary as *T*, the recurrence inter
changes from 1.2 to 300 years. The *a* coefficient shows an abrupt change between 10 and
years because the variable *I*, rainfall intensity, has not been used below 25 years. The ot
coefficients all show consistent and smooth variations with recurrence intervals. The variati
in coefficients *b*, *c*, *e*, *f*, and *g* have been tested and found statistically significant. The variati
in the coefficient, *d*, for surface storage, were not found significant although *d* appears to v
uniformly with recurrence interval. For this reason a constant value, — 0.3, has been u
throughout in the final set of equations.

Table 3 is a summary of simplified regression coefficients *b* through *g* selected from
curves of figure 6 and rounded to the nearest one/tenth in value. This simplification is acc

hed with no appreciable loss of accuracy in the final equations. The *a* coefficients as shown recomputed values which, on theoretical grounds, balance the simplified values of the other fficients.

TABLE 3

SUMMARY OF SIMPLIFIED REGRESSION COEFFICIENTS

$$Q_T = a A^b S^c St^d I^e t^f O^g$$

ecurrence terval, *T*, in years	Regression Coefficients							Standard error in percent
	a	*b*	*c*	*d*	*e*	*f*	*g*	
1.2	2.14	1.0	.3	—.3	0	.4	.8	24.9
2.33	2.60	1.0	.4	—.3	0	.4	.8	23.2
5	3.54	1.0	.4	—.3	0	.4	1.0	26.6
10	4.52	1.0	.4	—.3	0	.4	1.1	28.4
25	2.08	1.0	.5	—.3	.5	.4	1.1	29.3
50	2.26	.9	.4	—.3	.9	.5	1.1	27.2
100	1.38	.9	.4	—.3	1.1	.6	1.2	32.6
200	1.01	.9	.3	—.3	1.2	.8	1.5	33.0
300	0.681	.9	.3	—.3	1.3	.9	1.6	37.2

The final column of table 3 shows the standard errors of estimate at each flood level. ese are considered acceptable limits considering the nature of the problem.

The multiple-correlation equations apply only in New England within the limits of the a used to develop the relations. The results apply only to essentially unregulated conditions— ghly to basins with less than 4.5 million cubic feet of usable storage per square mile. Although a for drainage areas between 1.64 and 9,700 square miles were used in the analysis, the small nber of stations below 10 square miles leave the results uncertain in that range. Because flood experience is of necessity based on a given period of record, results must be considered pplicable to the events during that period. They can be used for prediction only if it is assumed t the general level of flood activity will be the same in the future period under consideration in the past. It is believed that, irrespective of the general level of floods represented, the tive effect of the separate hydrologic factors for the New England region is fairly well defined this study.

The approach used here might prove profitable in any humid region. Modifications in variables used may be made as found necessary because of local conditions or because of type of data available. Further study is being made in the arid and semiarid southwestern ited States.

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MAPPING MEAN AREAL PRECIPITATION

D.R. DAWDY and W.B. LANGBEIN
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ABSTRACT

A method is presented for using point mean precipitation data to estimate areal va in regions of high relief. Variation of precipitation with altitude is determined. Local anom from this relationship are mapped, and lines of equal anomaly are drawn. By use of the m relation corrected for the local anomaly, the mean precipitation at any point can be determi and an isohyetal map drawn. A similar approach can be used to determine mean tempera for studies of snowmelt or of potential evapotranspiration.

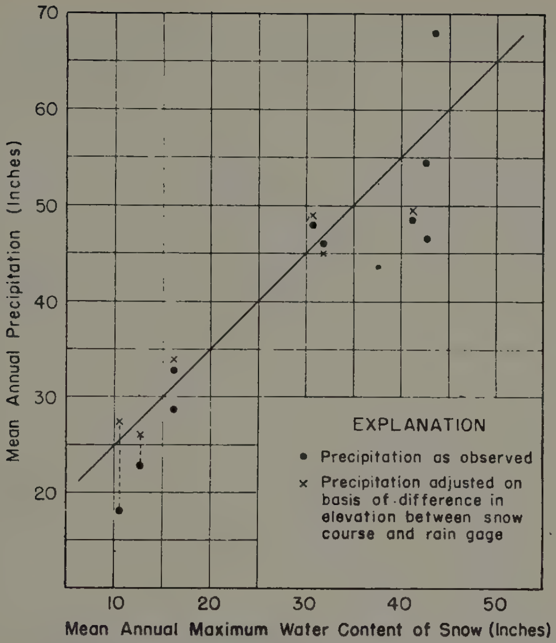
For many hydrologic studies, areal mean rainfall is an important factor. In regions of relief, point rainfall data may be used to extrapolate mean areal values with fair accur In the mountainous country, two factors render this extrapolation more inexact. First, r of the mountainous region is sparsely populated, and since the density of the raingaging work is a function of population, there are few rain gages. Second, most gages measure rai in the valley, so that an estimation of the rainfall in the mountains is difficult.

Various methods can be used to extend the available data. One method is to sketch hyetal lines on the basis of recorded precipitation using altitude as a guide. Another me is to divide the region under study into sections on the basis of topography and directio storm travel and to define separate relations between altitude and precipitation for each sect A more sophisticated method is to correlate available records of precipitation with o details of the terrain surrounding the location of the rain gage as well as with altitude. Fac used by Russler and Spreen (1947) included, for example, the exposure, the orientation o landscape, a « zone of environment », and altitude. However, a consideration of these fac seemed to indicate that altitude and zone of environment accounted for a major part o regional variation in precipitation. The following simpler technique was evolved for map mean areal precipitation in connection with a study of the hydroclimatology of the Ca Creek basin, a 650 square/mile tributary to the Big Wood River in southern Idaho. The vation of the basin ranges from 4,870 feet at the gaging station on Camas Creek near B to 6,830 feet on the southern rim, with a maximum of 10,080 feet on the northern rim. though about two-thirds of the basin lies below 5,500 feet, the average elevation o basin is about 5,800 feet.

DATA AVAILABLE

Mean annual precipitation and altitude for 42 stations in and near the Camas and Wood basins were available from the U.S. Weather Bureau, and data for 9 mountain s courses were available from the U.S. Soil Conservation Service. Records at 31 stations of sufficient length and quality to use the reported averages. Records at 9 other stations less than 5 years long. For these stations the means of record were adjusted by compa with records at nearby long-term stations. Snow-course data as well as records obtaine mountain storage gages (precipitation gages read at the onset and close of winter) are spec valued because of data they provide on precipitation at high altitudes.

In order to estimate the precipitation for the snow courses, the maximum inches of v in the snow was abstracted from the Summary of Snow Survey Data for the Columbia F



. 1 — Relation between Mean annual precipitation and mean annual maximum water content of snow.

sin, June 1953, for 10 stations where both snow and total precipitation data were collected. ese data were plotted against mean annual precipitation to define a relationship between w survey data and annual precipitation (See fig. 1). This relationship then was applied to 9 snow-survey data stations pertinent to this study.

ECIPITATION-ALTITUDE RELATION

The first step in the study was the preparation of a trial relationship between precipitation l altitude. For all 51 stations, mean annual precipitation was plotted against altitude and end line was drawn. Figure 2 shows the results for this study. The slope of the trend line, ed the hyeto-lapse rate, indicates an increase of 10 inches per 1,000 feet of altitude.

The hyeto-lapse rate of 10 inches per 1,000 feet is greater than most studies in the United tes show. Lee (1911) stated that annual precipitation on the windward side of the Sierra vada increases at a rate of 8.5 inches per 1,000 feet up to an altitude of 5,000 feet, and decreases ve. Henry (1919) gives many lapse rates ranging from almost nothing on the west slopes South America to 10 inches per 1,000 feet at Assam, India. He gives a rate of 8.5 inches per 00 feet for the southern Sierra Nevada, 6 inches per 1,000 feet for southern California, and inches per 1,000 feet for eastern Idaho. The latter is a close check of the results of the present dy. All values greater than 10 inches are for areas outside the United States, and mainly for tropical areas.

The U.S. Weather Bureau (1953) in a study of the hydrometeorology in the Snake River on, which includes the Camas River basin, reports hyetolapse rates ranging from 4 to 4.7 nes per 1,000 feet. Although these results indicate that the hyeto-lapse rate indicated in

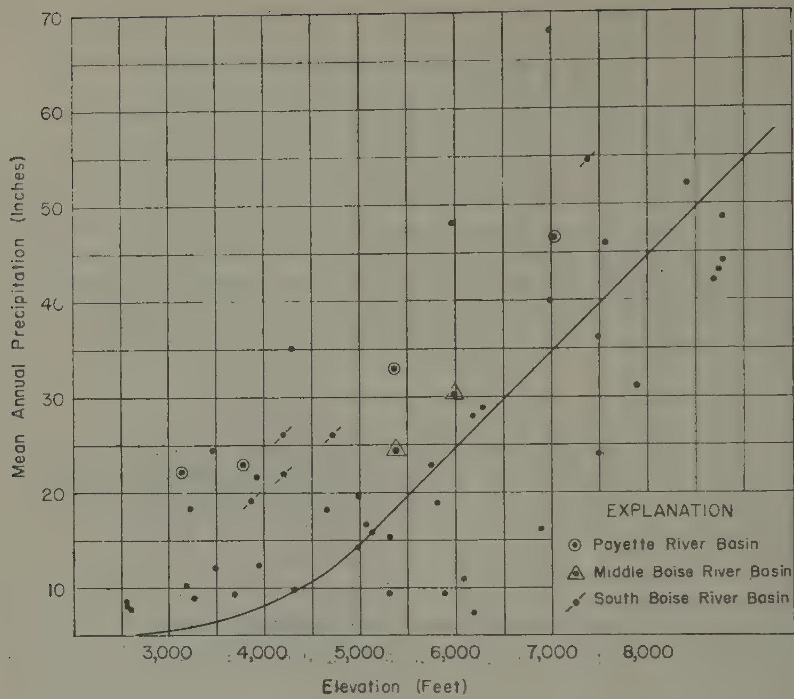


Fig. 2 — Relation between mean annual precipitation and altitude

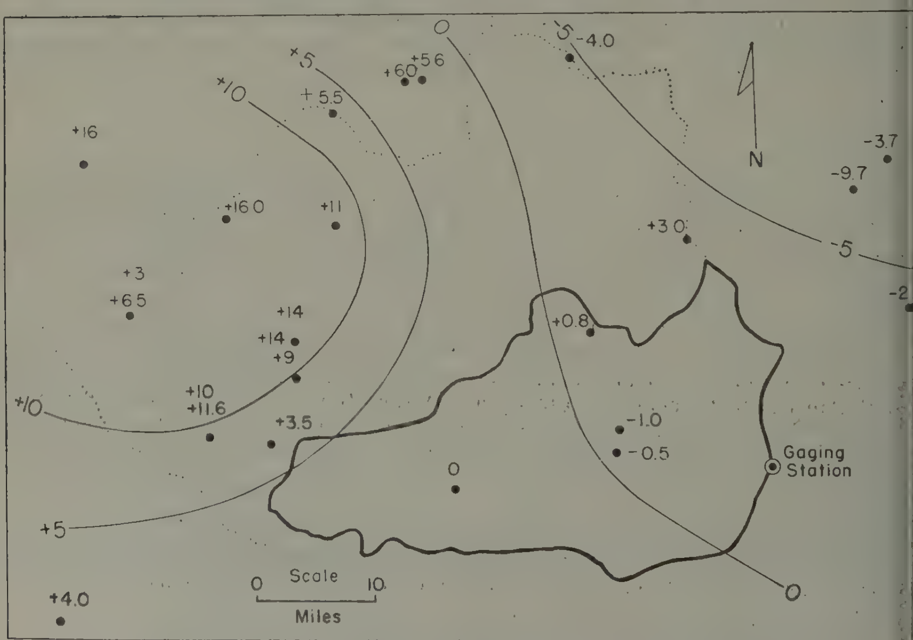


Fig. 3 — Map of Camas Creek and adjouning region showing precipitation anomalies

ire 2 may be an overestimate, the data seem to confirm a rate of 10 inches per 1,000 feet for region.

CIPITATION-ANOMALY MAP

Deviations from the trend line of the precipitation-altitude relation were plotted as anomalies on a map of the area, and lines of equal anomaly were drawn (see fig. 3).

The geographical spacing of the anomalies appears very consistent, with large positive malies to the west and large negative anomalies to the east. This variation in the anomalies onsistent with the general weather pattern in the Camas Creek basin. The general movement torms is from west to east, and each basin is in the rain shadow of the mountain ridge to west.

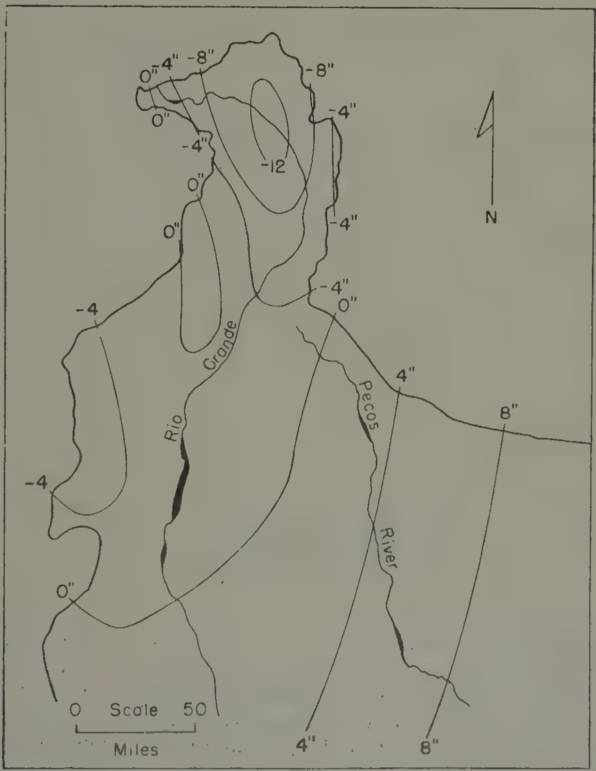


Fig. 4 — Map of upper Rio Grande basin showing precipitation anomalies.

Figure 4 shows a similar map of anomalies for the Upper Rio Grande region derived by A. Benson, hydraulic engineer of the U.S. Geological Survey. Here again the pattern shows nooth gradation but with increasing trend from west to east. The deep rain shadow of the Luis Valley in the upper reaches of the Rio Grande shows up clearly. This area partly laps the area studies by Russler and Spreen (1947). Benson's study agrees quite well their results. Of the drainage basin rainfall values computed by both methods, about

one-half were within five percent of each other. Over two-thirds were within 10 percent. T lapse rate (in the Upper Rio Grande region) was 3 ½ inches per 1,000 feet.

If there is uncertainty about the altitude-percipitation relation, its position can be fix more definitely by the following procedure. Values of the anomalies are read from the smoc iso-anomalies and then applied with reversed algebraic sign to the values of the observed pre pitation. The values of precipitation so adjusted are replotted against the altitude. These da then define a precipitation-altitude relationship quite closely. The re-defined altitude relationsh can be used to compute and re-define the lines of iso-anomalies. The re-defined precipitatic altitude relationship for the Camas Creek region shown on figure 5 confirms the origi shown on figure 2.

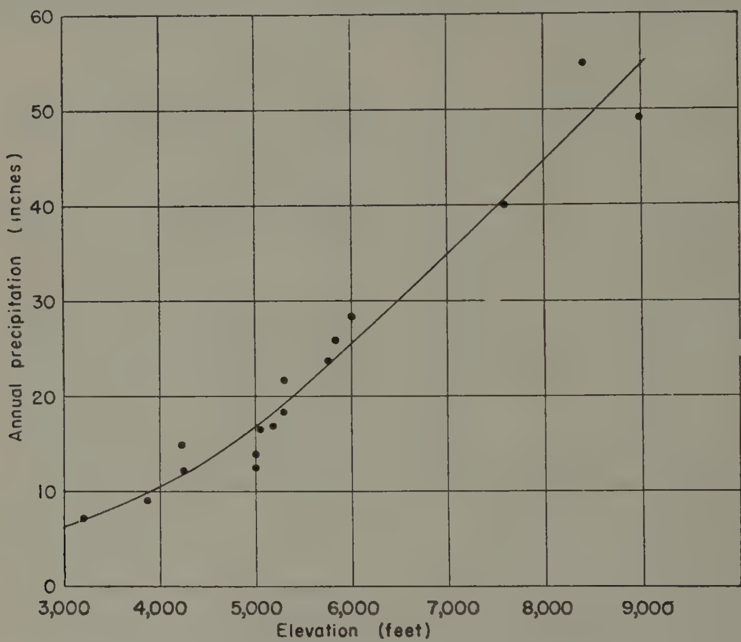


Fig. 5 — Re-defined precipitation-altitude relationship

The preparation of a precipitation map follows quite readily. For each line of equal a maly, the relation of precipitation to altitude is one parallel to the general trend line, wit correction of the amount of precipitation by the amount of anomaly. For example, the plus anomaly line uniformly has 10 inches more precipitation at a given altitude than the gene trend line shows. For places between lines of equal anomaly interpolation is necessary.

Whereas the altitude-precipitation graph and the chart of iso-anomalies are quite smoc the isohyetal lines following the topography would be quite irregular. Therefore, for ma applications, it may not be necessary to go to the labor of drawing the isohyetal chart, as precipitation for any given place can be computed quite readily from its altitude and its knc geographic position on the anomaly chart.

The method described in this paper could be applied not only to the mapping of m annual precipitation but also to mapping seasonal precipitation as well. An even better relati ship might be found for seasonal precipitation since there may be more uniform storm patte within shorter periods. A more uniform storm pattern probably would result in a closer def tion of the iso-anomaly lines.

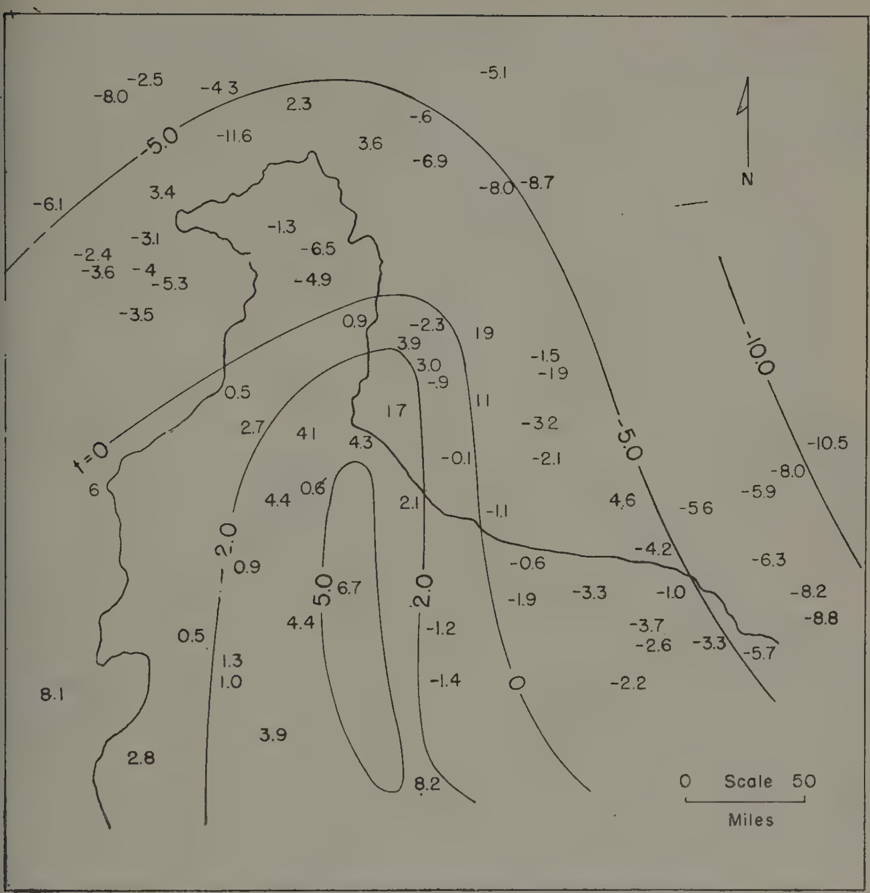


Fig. 6 — Map of upper Rio Grande basin showing January temperature anomalies .

ERATURE-ANOMALY MAP

A technique similar to that described for determination of the areal precipitation pattern e applied to the definition of the areal variation of temperatures over broad areas. In tudies of the flood hydrology of the Upper Rio Grande basin in Colorado and New co, M.A. Benson also has applied this procedure to mapping January temperatures. A onship between mean January temperatures and altitude indicated a temperature lapse of 4.5° F per thousand feet. Anomalies from this relationship were then plotted on a map e area, and lines of equal anomaly were drawn (see fig. 6).

TABLE 1

MEAN PRECIPITATION AND ELEVATION FOR WEATHER STATIONS IN AND ABOUT CAMAS AND BIG WOOD BASINS

Station	Elevation above mean sea level (feet)	Mean precipitation (inches)
Weather Bureau normals listed in 1955 issue of Climatological Data		
Arco	5,320	9.43
Arrowrock Dam	3,239	18.30
Bliss	3,269	8.80
Chilly Barton Flat	6,200	7.45
Deadwood Dam	5,375	32.87
Garden Valley RS	3,147	22.14
Glenns Ferry	2,569	8.58
Gooding AP	3,696	9.27
Grand View	2,600	7.66
Grouse	6,100	10.94
Hailey	5,322	15.33
Hill City	5,000	14.09
Idaho City	3,940	21.48
Island Park Dam	6,300	28.76
Lowman	3,800	22.95
Mackay RS	5,897	9.33
Mountain Home 1NE	3,180	10.02
Obsidian 4NNE	6,900	16.10
Richfield	4,306	9.73
Shoshone	3,955	10.23
Sun Valley	5,821	18.88
Climatic Summary to 1930 and supplement, 1931-52		
Anderson Dam	3,882	19.17
Atlanta	5,390	24.35
Atlanta 1E	6,000	30.12
Garnet	2,575	8.03
Little Camas	5,000	19.48
Pine 2SSW	4,225	21.88
Soldier	5,140	15.82
Soldier Creek	5,755	22.83
Sunnyside	3,500	12.02

TABLE 1 (*continued*)

tion	Elevation above mean sea level (feet)	Mean precipitation (inches)
	Estimated from current short-term records	
inta Summit	7,590	46
terville	4,300	35
rfield	5,065	16.5
ore Creek	5,990	48
e 1N	4,220	26
ke Creek	4,730	26
iity Lake	7,400	54.5
utdale	3,475	24.3
ina	8,800	48.5
	Estimated from snow courses	
l Mountain	8,700	42
ch Summit	7,000	25
ena	7,500	20.8
ena Summit	8,795	29.4
ham Ranch	6,200	13.3
chum	8,421	52
t Wood Divide	8,750	28.2
scot Mine	7,900	15.8
kney Mill	7,500	9.0
	Estimated from short-period storage gages	
dwood Summit	7,000	68
son Peak	7,050	46.5

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ENQUETE SUR LES CARACTERISTIQUES CHIMIQUES ET PHYSIC CHIMIQUES DES EAUX DU PO A POLESELLA ET RECHERC DES MATIÉRES DISSOUTES DANS L'EAU AU MOYEN D'ANALYS CHIMIQUES QUANTITATIVES ET SPECTROGRAPHIQUES SEN QUANTITATIVES

Prof. Ing. Luigi Gherardelli
Dott. Ing. Lamberto Canali

1) — *Avant-propos*

En 1959 le Bureau Hydrographique du Po accueillant une proposition faite par l'Asso tion Internationale d'Hydrologie Scientifique au cours de la Réunion de l'Assemblée Géné de Toronto au mois de septembre 1957 a commencé une enquête sur les matières dissou dans les eaux du Pô et sur leur variabilité selon le régime des écoulements — Cette ét consistait en une série d'analyses chimiques et spectrographiques sur des échantillons d'e étant donné qu'il s'agissait de la première campagne d'enquêtes sur ce sujet, qu'on de par conséquent considérer comme ayant ur caractère d'information, on a jugé convenable limiter à quatre le nombre des échantillons à analyser, conformément, du reste, aux directi indiquées, (en principe), par l'Association mentionnée.

Si le Service Hydrographique du Po aura la possibilité de continuer à l'avenir l'étude en prise, on pourra considérer la nécessité de varier la manière et la fréquence des prélèveme compte tenu, naturellement, des résultats obtenus à présent — Les prélèvements ont effectués dans les conditions d'écoulement suivantes :

— en eaux basses (prélèvement du 25.2.59 — Q = 800 m3/sec.)

— en eaux hautes, en coïncidence avec l'intensité max. de crue (prélèvement du 4.5.5 Q = 4.700 m3/sec.)

— pendant la phase de croissance d'une crue (prélèvement du 18.11.58 — Q = 4.120 /sec.)

— durant la phase décroissante de la même crue (prélèvement du 24.11.59 — C 2.984 m3/sec.)

Pour chaque analyse on a prélevé 20 litres d'eau, lesquels filtrés sur place avec des fil Whatmann, du type à filtrage rapide, étaient recueillis dans des récipients de polyéthylè pendant qu'on recueillait, à part, dans une bouteille en verre 2 litres de la même eau pour déterminations du fer et du manganèse.

Les échantillons étaient remis au Laboratoire d'Analyses dans les 24 heures à pa de l'heure du prélèvement pour les premières et immédiates déterminations que le Laborat même devait effectuer.

Avec chaque échantillon on envoyait au Laboratoire une fiche avec l'indication conditions atmosphériques pendant le prélèvement; du débit du cours d'eau, des caractéristic physiques de l'eau et de la température de l'eau et de l'air au moment du prélèvement.

Tous les échantillons ont été prélevés à la section de Polesella, située à 24 Km envi en amont du delta du Po, qui comprend un bassin versant de 70091 Km2; les prélèveme étaient effectués sur la ligne centrale du courant à la surface des eaux — Les analyses ont faites au Laboratoire chimique Provincial de Bologne qui a été effectuée sous la direction M. le Dr. Mario Mengoli, un travail très soigné et scrupuleux.

Sur chaque échantillon on a effectué une analyse chimique quantitative en indiquant p.p. m. les substances recherchées; on a effectué de même les déterminations de certaines c

ues physico-chimiques et d'autres encore, telles que la dureté totale et permanente; l'alcalinité,
— Sur les mêmes échantillons d'eau on a effectué successivement l'analyse spectographique i-quantitative qui, tout en fournissant un contrôle des résultats de l'ananlyse chimique ntitative, permettait la détermination d'un plus grand nombre d'éléments.

Le pourcentage des éléments recherchés a été exprimé avec nombres de la série -1-0.3 —0.1, etc.

our les éléments recherchés on a indiqué sur les certificats les symboles suivants :

— élément non recherché : —

— élément recherché mais absent : o

— *Résultat des analyses*

I^er^ Certificat

— *Echantillon* : eau du Po prélevée le 25.2.59 de 9 h 30 à 13 h 30.

— *Conditions atmosphériques* : Ciel couvert jusqu'à 10 h 30 ensuite soleil modéré.

— *Conditions du fleuve*: eaux basses (soutenues). Débit approximatif: 800 m3/sec. environ.

— *Caractéristiques physiques de l'eau remise au laboratoire* : limpide, sans odeur, pratiquement incolore. Absence de sédiment notable au moment du prélèvement. Après repos, abonce de sédiment poussiéreux et jaunâtre.

— *Constantes physico-chimiques* :

— Température de l'eau, à 11 h 30	7°.5 C.
— Température de l'air, à 11 h 30	13°.0 C.
— Acidité actuelle par voie électrométrique (pH)	7.25
— Conductivité électrique spécifique à 25° C. µS	409.2
— Couleur (déterminée avec une solution platine-cobalt selon la Standard Méthode)	18 unités

— *Détermination quantitative* (exprimée en p.p.m.)

Silice	($Si\ O_2$)	5.50
Fer	(Fe)	0.196
Manganèse	(Mn)	0.004
Calcium	(Ca)	60.62
Magnésium	(Mg)	12.92
Sodium	(Na)	17.00
Potassium	(K)	2.20
Bicarbonates	(HC 03)	187.20
Carbonates	(C 03)	6.00
Sulfates	(SO_4)	53.08
Chlorures	(Cl)	19.75
— Fluorures	(F)	0.09
— Nitrates	(NO_3)	pratiquement absents.

— *Déterminations diverses* :

Substances solides en solution (calculées)	mg/l 264.96
Résidu fixe à 180° C.	mg/l 265.40
Dureté totale (en degrés français)	20° 5
Dureté permanente (en degrés français)	9°.8
Alcalinité (en Ca CO_3)	mg/l 153.50

— Analyse spectrographique semi-quantitative :

Silicium	(Si)	mg	0.3	pour cent	gr d'eau
Aluminium	(Al)	»	0.0001	%	» »

Fer	(Fe)	»	0.03	%	gr	d'eau
Magnésium	(Mg)	»	1.0	%	»	»
Calcium	(Ca)	mg	3.0	%	»	»
Sodium	(Na)	mg	1.0	%	»	»
Titane	(Ti)		–			
Phosphore	(P)		0			
Manganèse	(Mn)	mg	0.0003	%	»	»
Argent	(Ag)	»	0.00003	%	»	»
Arsénic	(As)		0			
Or	(Au)		0			
Barium	(Ba)	mg	0.1	%	»	»
Bora	(B)		–			
Beryllium	(Be)		0			
Bismuth	(Bi)		0			
Cadmium	(Cd)		0			
Cerium	(Ce)		0			
Cobalt	(Co)		0			
Chromé	(Cr)	mg	0.0001	%	»	»
Cesium	(Cs)		0			
Cuivre	(Cu)	»	0.0001	%	»	»
Disprosium	(Dy)		–			
Erbium	(Er)		–			
Europium	(Eu)		–			
Fluor	(F)	mg	0.01	%	»	»
Gadolinium	(Gd)		–			
Gallium	(Ga)		0			
Germanium	(Ge)		–			
Hafnium	(Hf)		–			
Mercure	(Hg)		0			
Hélium	(He)		–			
Indium	(In)		0			
Iridium	(Ir)		–			
Lantanium	(La)		–			
Litium	(Li)	mg	0.01	%	»	»
Lutetium	(Lu)		–			
Molibdène	(Mo)		0			
Niobium	(Nb)		–			
Neodimium	(Nd)		–			
Nikel	(Ni)	mg	0.0003	%	gr	d'eau
Osmium	(Os)		–			
Plomb	(Pb)	mg	0.001	%	»	»
Palladium	(Pd)		0			
Praseodimium	(Pr)		–			
Platine	(Pt)		0			
Rubidium	(Rb)		0			
Rhenium	(Re)		–			
Rhodium	(Rh)		–			
Antimonio	(Sb)		0			
Scandium	(Sc)		–			
Etain	(Sn)	mg	0.01	%	»	»
Strontium	(Sr)	»	0.1	%	»	»
Samarium	(Sm)		–			
Tantale	(Ta)		–			
Terbium	(Tb)		–			

Tellure	(Te)		–			
Torium	(To)		–			
Tallium	(Tl)		–			
Tullium	(Tm)		–			
Uranium	(U)		–			
Vanadium	(V)		–			
Tungstène	(W)		0			
Ytthrium	(Y)		0			
Yttherbium	(Yb)		–			
Zinc	(Zn)	mg	0.0001	%	»	»
Zirconium	(Zr)		–			

IIme Certificat

Echantillon : eau du Po prélevée le 4.5.59 de 10 h à 17 h.

Conditions atmosphériques : ciel clair

Conditions du fleuve : crue, à cause des eaux du Piémont

Caractères physiques de l'eau apportée au Laboratoire :
— Trouble, jaunâtre, sans odeur — Après un repos elle reste opalescente et il se forme dépôt floculeux jaunâtre —

Constantes physico-chimiques :

— Température de l'eau	13°.0 C
— Température de l'air	19°.0 C
— Acidité actuelle par voie électrométrique (pH)	7,7
— Conductibilité électrique à 25° C	µS 224,7
— Couleur (déterminée avec une solution platine-cobalt selon la Standard Méthode	22/unités

Détermination quantitative (exprimée en p.p.m.)

Silice	($Si\ O_2$)	8.60
Fer	(Fe)	0.811
Manganèse	(Mn)	0.012
Calcium	(Ca)	33.61
Magnésium	(Mg)	8.37
Sodium	(Na)	7.00
Potassium	(K)	1.80
Bicarbonates	(HCO_3)	108.10
Carbonates	(CO_3)	absents
Sulfates	(SO_4)	29.05
Chlorures	(Cl)	9.00
Fluorures	(F)	0.35
Nitrates	(NO_3)	traces non dosables

Déterminations diverses :

Substances solides en solution (calculées)	mg/l	164.999
Résidu fixe à 180° C	»	165.60
Dureté totale (en degrés français)		11°.8
Dureté permanente (en degrés français)		7°.8
Alcalinité (en $CaCO_3$)	mg/l	88.60

Analyses spectrographique semi-quantitative .

Silicium	(Si)	mg	0.3	%	gr	d'eau
Aluminium	(Al)	»	0.00001	%	»	»
Fer	(Fe)	»	0.1	%	»	»
Magnésium	(Mg)	»	1.0	%	»	
Calcium	(Ca)	»	3.0	%	»	»
Sodium	(Na)	»	1.0	%	»	»
Potassium	(K)	»	0.1	%	»	»
Titane	(Ti)		–			
Phosphore	(P)		0			
Manganèse	(Mn)	»	0.001	%	»	»
Argent	(Ag)	»	0.00001	%	»	»
Arsénic	(As)		0			
Or	(Au)		0			
Bore	(B)		–			
Barium	(Ba)	mg	0.03	%	»	»
Beryllium	(Be)		0			
Bismuth	(Bi)		0			
Cadmium	(Cd)		0			
Cerium	(Ce)		0			
Cobalt	(Co)		0			
Chrome	(Cr	mg	0.00003	%	»	»
Cesium	(Cs)		0			
Cuivre	(Cu)	mg	0.00003	%	»	»
Disprosium	(Dy)		–			
Erbium	(Er)		–			
Europium	(Eu)		–			
Fuore	(F)	mg	0.03	%	»	»
Gadolinium	(Gd)		–			
Gallium	(Ga)		0			
Germanium	(Ge)		–			
Hafnium	(Hf)		–			
Mercure	(Hg)		0			
Hélium	(He)		–			
Indium	(In)		0			
Iridium	(Ir)		–			
Lanthanium	(La)		–			
Lithium	(Li)	mg	0.003	%	»	»
Lutétium	(Lu)		–			
Mobildène	(Mo)		0			
Niobium	(Nb)		–			
Nickel	(Ni)	mg	0.001	%	»	»
Osmium	(Os)		–			
Plomb	(Pb)	mg	0.0001	%	»	»
Palladium	(Pd)		0			
Praseodimium	(Pr)		–			
Platine	(Pt)		0			
Rubidium	(Rb)		0			
Rhenium	(Re)		–			
Rhodium	(Rh)		–			
Rutenium	(Ru)		–			
Antimone	(Sb)		0			
Scandium	(Sc)		–			
Etain	(Sn)	mg	0.01	%	»	»

Strontium	(Sr)	0.03	%	gr. d'eau
Samarium	(Sm)	–		
Tantale	(Ta)	–		
Terbium	(Tb)	–		
Tellure	(Te)	–		
Thorium	(Th)	–		
Tallium	(Tl)	–		
Tullium	(Tm)	–		
Uranium	(U)	–		
Vanadium	(V)	–		
Tungstène	(W)	0		
Ytthrium	(Y)	0		
Yttherbium	(Yb)	–		
Zinc	(Zn)	mg. 0.00001	%	» »
Zirconium	(Zr)	–		

IIme Certificat

Echantillon : eau du Pô prélevée le 18.11.1959.

Conditions atmosphériques : — pluie d'intensité variable — vent de N.O.

Conditions du fleuve: — en phase avancée de crue croissante due à des précipitations :out le bassin du Pô, avec une forte précipitation sur le versant et fonte de neige ıte — Débit moyen du fleuve à Pontelagoscuro, pendant le prélèvement = 4120 m³/s.

Caractéristiques physiques de l'eau apportée au Laboratoire: — couleur opale à peine remar-le sans odeur, limpide après repos, avec quelque sédimentation poussiéreuse et jaunâtre.

Constantes physico-chimiques

Température de l'eau : 9.6° C au début du prélèvement;
9.7° C à la fin du prélèvement.
Température de l'air 11.0° C
Acidité actuelle par voie électrométrique (pH) 7.9
Conductibilité électrique spécifique à 25° C μS 312.5
Couleur (déterminée avec une solution platino-cobalt selon la Standard Méthode) 11 unités

— *Déterminations quantitatives* (exprimées en p.p.m.)

Silice	(SiO_2)	5.00
Fer	(Fe)	0.25
Manganèse	(Mn)	0.027
Calcium	(Ca)	49.22
Magnésium	(Mg)	10.39
Sodium	(Na)	9.70
Potassium	(K)	2.80
Bicarbonates	($HC\ O_3$)	157.10
Carbonates	($C\ O_3$)	absents
Chlorures	(Cl	13.00
Sulfates	(SO_4)	34.57
Fluorures	(F)	0.10
Nitrates	(NO_3)	5.856

— *Déterminations diverses*

— Substances solides en solution (calculées)	p.p.m.	209.46
— Résidu fixe à 180° C	»	211.20
— Dureté en degrés français — totale		16°.6
— permanente		9°.4
— Alcalinité (en Ca CO_3)	p.p.m.	128.70

— *Analyse spectrographique semi-quantitative*

Silicium	(Si)	mg	0.3	pour cent	gr	d'eau
Aluminium	(Al)	»	0.0003	%	»	»
Fer	(Fe)	»	0.03	%	»	»
Magnésium	(Mg)	»	1.0	%	»	»
Calcium	(Ca)	»	3.0	%	»	»
Sodium	(Na)	»	1.0	%	»	»
Potassium	(K)	»	0.3	%	»	»
Titane	(Ti)		–			
Phosphore	(P)		0			
Manganèse	(Mn)	»	0.003	%	»	»
Argent	(Ag)	»	0.00001	%	»	»
Arsenic	(As)	»	0.0003	%	»	»
Or	(Au)		0			
Bore	(B)		–			
Barium	(Ba)	»	0.1	%	»	»
Beryllium	(Be)		0			
Bismuth	(Bi)		0			
Cadmium	(Cd)		0			
Cerium	(Ce)		0			
Cobalt	(Co)		0			
Chrome	(Cr)	»	0.00003	%	»	»
Cesium	(Cs)		0			
Cuivre	(Cu)	»	0.00003	%	»	»
Dysprosium	(Dy)		–			
Erbium	(Er)		–			
Europium	(Eu)		–			
Fluore	(F)	mg	0.01	pour cent	gr.	d'eau
Gadolinium	(Gd)		–			
Gallium	(Ga)		0			
Germanium	(Ge)		–			
Hafnium	(Hf)		–			
Mercure	(Hg)		0			
Hélium	(He)		–			
Indium	(In)		0			
Iridium	(Ir)		0			
Lantanium	(La)		–			
Litium	(Li)	mg	0.003	%	»	»
Lutétium	(Lu)		–			
Molibdène	(Mo)		0			
Nyobium	(Nb)		–			
Néodymium	(Nd)		–			
Nickel	(Ni)	mg	0.0001	%	»	»
Osmium	(Os)		–			
Plomb	(Pb)	mg	0.0003	%	»	»
Palladium	(Pd)		0			
Praseodimium	(Pr)		–			

Platine	(Pt)		0		
Rubidium	(Rb)		0		
Rhenium	(Re)		–		
Rhodium	(Rh)		–		
Rutenium	(Ru)		–		
Antimoine	(Sb)		0		
Scandium	(Sc)		–		
Etain	(Su)		0		
Strontium	(Sr)	mg	0.03	%	gr d'eau
Samarium	(Sm)		–		
Tantalium	(Ta)		–		
Terbium	(Tb)		–		
Tellurium	(Te)		–		
Thrium	(Th)		–		
Tallium	(Tl)		–		
Tullium	(Tm)		–		
Uranium	(U)		–		
Vanadium	(V)		–		
Tungstène	(W)		0		
Ytthrium	(Yi)		0		
Yttherbium	(Yb)		–		
Zinc	(Zn)	mg	0.0001	%	» »
Zirconium	(Zr)		–		

IV^me Certificat

Echantillon : eau du Pô prélevée le 24.11.59 de 8 h 45 à 11 h 30.

Conditions atmosphériques — ciel clair

Conditions du fleuve — en décroissement — Débit moyen du fleuve Pontolagoscuro pendant prélèvement = 2.984 m3/s.

Caracteristiques physiques de l'eau apportée au Laboratoire — couleur opaline à peine table, sans odeur, limpide après repos, avec une sédimentation poussiéreuse et jaunâtre.

Constantes physico-chimiques —

Température de l'eau 8.8° C

Température de l'air : 6.3° C au début du prélèvement; 9.4° C à la fin du prélèvement

Acidité actuelle par voie électrométrique (pH) 8.05

Conductibilité électrique à 25°6 µS 352.8

Couleur (déterminée avec une solution de platino-cobalt selon la Standard Méthode) 9 unités

— *Déterminations quantitatives* (exprimées en p.p.m.)

Silice	($Si\ O_2$)	6.50
Fer	(Fe)	0.22
Manganèse	(Mn)	0.033
Calcium	(Ca)	51.80
Magnésium	(Mg)	10.98

Sodium	(Na)	10.40
Potassium	(K)	2.90
Bicarbonates	(HCO_3)	172.70
Carbonates	(CO_3)	absents
Sulfates	(SO_4)	35.31
Chlorures	(Cl	13.00
Fluorures	(F)	0.12
Nitrates	(NO_3)	2.74

— *Déterminations diverses* —

Substances solides en solution (calculées)	p.p.m.	220.355
Résidu fixe à 180° C	»	221.40
Dureté en degrés français — totale		17°.6
— permanente		9°.5
Alcalinité en (Ca CO_3)	p.p.m.	141.60

— *Analyse spectrographique semi-quantitative* :

Silicium	(Si)	mg	0.3	pour cent	gr	d'eau
Aluminium	(Al)	»	0.0003	%	»	»
Fer	(Fe)	»	0.03	%	»	»
Magnésium	(Mg)	»	1.0	%	»	»
Calium	(Ca)	»	3.0	%	»	»
Sodium	(Na)	»	1.0	%	»	»
Potassium	(K)	»	0.3	%	»	»
Titane	(Ti)		–			
Phosphore	(P)		0			
Manganèse	(Mn)	»	0.003	%	»	»
Argent	(Ag)	»	0.00001	%	»	»
Arsenic	(As)	»	0.0001	%	»	»
Or	(Au)	»	0			
Bore	(B)		–			
Barium	(Ba)	»	0.03	%	»	»
Beryllium	(Be)		0	%		
Bismuth	(Bi)		0			
Cadmium	(Cd)		0			
Cerium	(Ce)		0			
Cobalt	(Co)		0			
Chrome	(Cr)	mg	0.0001	%	gr.	d'eau
Cesium	(Cs)		0			
Cuivre	(Cu)	»	0.00003	%	»	»
Dysprosium	(Dy)		–			
Erbium	(Er)		–			
Europium	(Eu)		–			
Fluore	(F)	»	0.01	%	»	»
Gadolinium	(Gd)		–			
Gallium	(Ga)		0			
Germanium	(Ge)		–			
Hafnium	(Hf)		–			
Mercure	(Hg)		0			
Hélium	(He)		–			
Indium	(In)		0			
Iridium	(Ir)		0			
Lantanium	(La)		–			

Litium	(Li)	mg	0.003	%	gr	d'eau
Lutetium	(Lu)		–			
Molibdène	(Mo)		0			
Niobium	(Nb)		–			
Néodimium	(Nd)		–			
Nickel	(Ni)	mg	0.0001	%	»	»
Osmium	(Os)		–			
Plomb	(Pb)	mg	0.0003	%	»	»
Palladium	(Pd)		0			
Praséodimium	(Pr)		–			
Platine	(Pt)		0			
Rubidium	(Rb)		0			
Rhénium	(Re)		–			
Rhodium	(Ro)		–			
Ruthenium	(Rh)		–			
Antimoine	(Sb)		0			
Scandium	(Sc)		–			
Etain	(Sn)		0			
Strontium	(Sr)	mg	0.03	%	»	»
Samarium	(Sm)		–			
Tantale	(Ta)		–			
Terbium	(Tb)		–			
Tellurium	(Te)		–			
Thorium	(Th)		–			
Tallium	(Tl)		–			
Tullium	(Tm)		–			
Uranium	(U)		–			
Vanadium	(V)		–			
Tungstène	(W)		0			
Ytthrium	(Y)		0			
Yttherbium	(Yb)		–			
Zinc	(Zn)	mg	0.0001	%	»	»
Zirconium	(Zr)		–			

– *Considérations sur les résultats des analyses chimiques quantitatives* —

Les déterminations quantitatives ont mis en évidence les caractèristiques de l'eau, qui ndent naturellement des terrains traversés.

Il s'agit d'une eau pauvre en silice et en carbonates et riche en calcium, bicarbonates et tes. Même le contenu en chlore est assez élevé.

Il n'est pas possible de reconnaître les éventuelles caractéristiques saisonnières du phé- ne en raison du faible nombre d'analyses dont on dispose; par contre on peut affirmer ous les éléments en solution ne subissent pas une dilution par l'augmentation du débit, au contraire, il y en a quelques-uns qui subissent de modestes augmentations.

A l'état actuel des enquêtes, les analyses quantitatives et les autres différentes déterminations ettent les considérations que nous exposons ci-dessous.

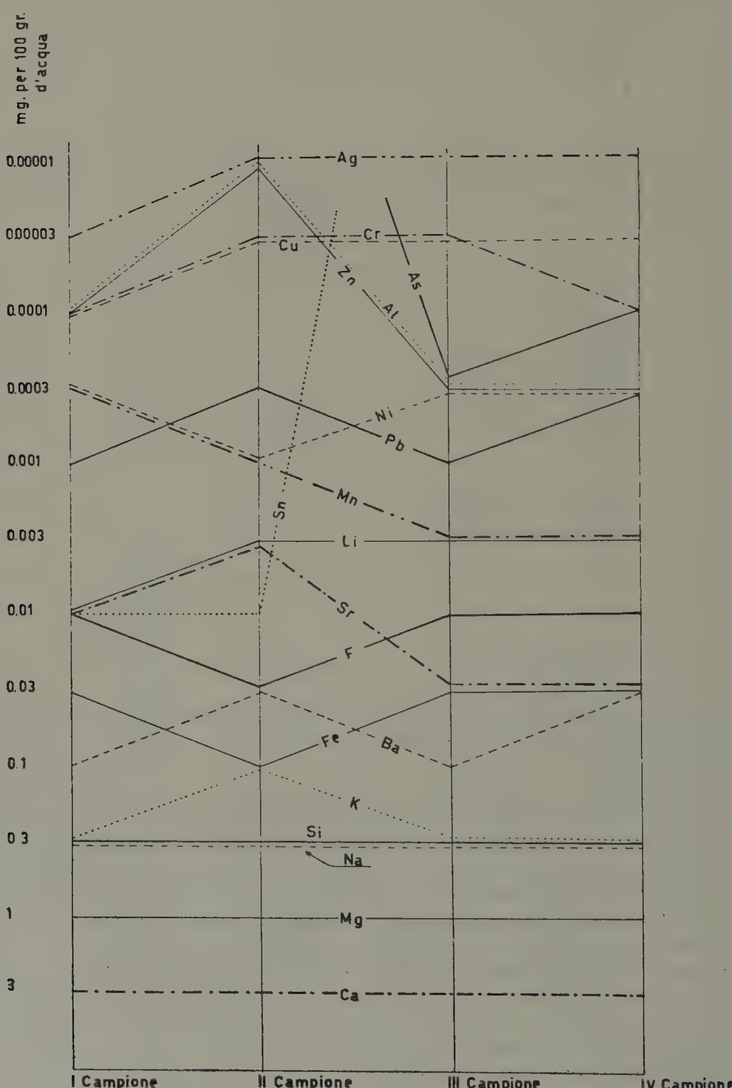
1. — en période de crue on note une dilution des composants minéraux, à l'exception silice et du fer dont la proportion devient sensiblement supérieure à celle présente en de d'étiage.

Ceci peut s'expliquér par le transport de sables argileux non parfaitement filtrés dans prise comme échantillon : substantiellement il s'agit d'une action plus active due aux ents en suspension.

En période de crue on remarque aussi une augmentation de fluor (environ 4 fois celle
période d'étiage).

Toutefois son contenu est relativement modeste (0.35 mg/1) : il peut donc être cons
comme normal même si l'eau devrait être employée comme eau potable.

2. — Dans les échantillons prélevés en phase croissante ou décroissante de crue on
la présence de nitrates, pratiquement absents dans les deux autres échantillons — La
pendant laquelle avaient été prélevés les échantillons qui révélaient la présence de nitrate
provoquée par des précipitations répandues sur tout le Compartiment, particulièrement re
quables sur le versant des Apennins, et par la fonte de neiges récente — On peut compre



intuition que les premières eaux météoriques qui déterminent la crue, en lavant le sol, hargent de produits dérivant de la décomposition des substances organiques.

Au fur et à mesure que la crue se forme, la forte dilution rend pratiquement indosables races de nitrates; pendant la phase décroissante il est à nouveau possible de déterminer résence de ceux-ci, qui sont d'ailleurs en quantité inférieure à celle de la phase croissante.

3. — La dureté totale est demeurée normale et en rapport avec le régime des débits : varie d'un maximum de 20°,5 (degrés français) en période d'étiage soutenu, à un minimum 1°,8 en période de crue — La dureté permanente se maintient beaucoup plus uniforme n la variation des débits — elle passe de 9°, 8 à l'étiage, à 7°,8 en phase de crue.

4. — L'alcalinité (en $CaCO_3$) varie avec le débit du fleuve et sa valeur passe de 88.60 mg/1 tiage à 153,50 mg/1 en phase de crue.

Dans tous les cas le degré d'alcalinité est toujours resté assez élevé.

5. — La quantité, calculée, de substances solides en solution dépend du degré de dilution est montré variable, dans les divers échantillons considérés, de 264,96 mg/1 à l'étiage à 99 mg/1 en crue.

6. — Le résidu fixe à 180° C, par contre, ne semble pas être influencé par l'état hydro-rique du fleuve, mais plutôt par la saison, car les échantillons de novembre ont donné des lus supérieurs à ceux de février et de mai.

7. — Sur tous les échantillons analysés l'eau a donné une réaction alcaline avec des valeurs H comprises entre 7.25 (en période d'étiage) à 8.05 (en phase de crue décroissante).

Il a semblé intéressant d'effectuer une enquête même sommaire, pour l'évaluation des tances dissoutes qui pendant une année moyenne s'écoulent à la mer.

Etant donné que la possibilité d'établir d'une façon satisfaisante un rapport entre le contenu ubstances solides en solution et le régime des écoulements n'existe pas en raison du faible bre d'échantillons disponibles, on a pris un contenu de substance dissoutes en une année, à la moyenne des quatre valeurs résultant des analyses, c'est-à-dire 214,94 mg/1. Etant né que le bassin versant du Po, à la section de Polesella, est de 70.091 Km2, soit 27.000 sq. , et que le débit moyen annuel relatif à l'année normale est de 1450 m3/s, correspondant .200 Cfs., la quantité de substances dissoutes qui affluent vers la mer en une année est de $\times 10^6$ tonnes, soit 10.8×10^6 tons.

Cette valeur est vraiment élevée et supérieure à ce qu'on pouvait attendre; il suffit de consi-r que la quantité de substances solides en suspension transportées dans l'année est de 12.3 $)^6$ tonnes, soit 13.5×10^6 tons, c'est-à-dire du même ordre de grandeur.

Cette conclusion, de grand intérêt, devra être confirmée par le prélèvement d'échantillons, essifs et nombreux dans le but de pouvoir établir une corrélation digne de foi entre le contenu fique des substances dissoutes et le régime des débits.

idérations sur les résultats des analyses spectrographiques

Les résultats des analyses spectrographiques qui, pour une plus évidente interprétation été représentés dans le diagramme de la fig 1, n'ont pas mis en évidence des singularités culières, mais, au contraire, elles ont confirmé les valeurs déjà déterminées par les analyses titatives.

La recherche a été étendue à 39 éléments; parmi ceux-ci, 18 se sont révélés absents dans les échantillons et deux autres absents chacun dans deux seuls échantillons.

Les éléments repérés sont ceux normalement présents à la surface des eaux et les tions constatées dans les divers échantillons, doivent être considérées comme normales. i les éléments recherchés on a constaté une variabilité moindre, par rapport aux débits, pour ceux présents en doses plus fortes : ceux-ci sont les composants des roches du bassin nt : le calcium-magnésium, le sodium, le silicium, et la potasse.

La présence de l'arsenic dans les phases de crue ascendante et décroissante mérite d'être culièrement remarquée — sa quantité est pratiquement très faible (0.003 mg/1); on doit rquer de même la présence de l'étain, mais en période d'étiage et de crue.

— Considérations générales sur les caractéristiques de l'eau du Pô à Polesella

A la lumière des résultats acquis par les analyses on juge utile d'exprimer aussi un juger même de principe, sur les données incomplètes dont on pouvait disposer, sur les caractéristi de l'eau du Pô à Polesella par rapport à son aptitude d'emploi pour l'irrigation ou cor eau potable, ainsi que son agressivité sur les constructions en béton.

Pour l'emploi agricole et potable, l'eau présente du point de vue physico-chimique de l nes qualités d'acceptabilité de son agressivité. Particulièrement en ce qui concerne l'irriga et la potabilité on doit remarquer que, étant donné qu'il s'agit d'eau dure à réaction basiq elle exerce une action assez utile sur les sols acides, plutôt fréquents dans les vastes territo agricoles de la basse vallée du Pô.

En ce qui concerne l'action agressive sur les ouvrages en béton on doit rappeler normalement on doit considérer dangereuse l'eau qui présente les conditions suivantes.

— contenu en anydride sulfurique $SO_3 \leqslant 40 \div 50$ mg/l

— dureté temporaire (degrés français) $D \geqslant 3.5 \div 4$; $pH \geqslant 7.30$.

Par conséquent même sous cet aspect les échantilions analysés ne peuvent causer auc préoccupation.

EFFECT ON EVAPORATION OF RELEASES FROM RESERVOIRS ON SALT RIVER, ARIZONA [1]

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TRACT .

By means of the energy-budget method, measurements of evaporation losses from four voirs on Salt River, Ariz., were determined to range from 57.5 to 69.9 inches for the 12-th period April 1958 to March 1959. Water is withdrawn from Roosevelt Lake at considerable h and released through three run-of-the-river reservoirs. Because the water released from sevelt Lake is cold, evaporation losses from the downstream reservoirs are considerably r than those from Roosevelt Lake. Evaporation pan coefficients computed for the various voirs ranged from 0.53 to 0.65. A base evaporation rate was computed for each reservoir e evaporation rate that would have occurred had there been no change in energy storage the net advected energy equalled zero during the year.

The U.S. Geological Survey in cooperation with the Salt River Valley Water Users Asso-on is making studies of the evaporation losses from the reservoirs in the Salt River reser- system using the energy-budget method. The results of these studies to date show that is a considerable difference in the evaporation rates at the four reservoirs in the system. also show a wide range in the ratio of reservoir to pan evaporation rates. Such studies de useful information for the better management of water resources, for the planning of e reservoir developments, and for use in the possible application of evaporation retardants ducing these losses.

The Salt River reservoir system consists of four reservoirs (fig. 1) that are used to store for irrigation and power. The largest reservoir of the system, formed by Roosevelt Dam, osevelt Lake, with a storage capacity of 1,382,000 acre-feet. The next reservoir is Apache with a storage capacity of 245,000 acre-feet, formed by Horse Mesa Dam 17 miles down-n from Roosevelt Dam. Ten miles below Horse Mesa Dam is Mormon Flat Dam, which Canyon Lake with a storage capacity of 58,000 acre-feet. Saguaro Lake, with a storage ity of 70,000 acre-feet, is formed by Stewart Mountain Dam 10 miles below Mormon Dam. Complete descriptions of the dams have been prepared by the Bureau of Reclamation). As shown in figure 1, each reservoir extends a long distance upstream from the dam so he channel distance from the head of a reservoir to the next dam upstream is only a small of the distance between dams given above.

The operation of the reservoir system depends on spring runoff and irrigation needs. ally most of the spring runoff is stored and releases are made during the summer for tion. These releases are usually made through outlets near the bottom of each reservoir the water is much colder than near the surface. All water released passes through the plant at the dam.

The reservoir system is in an arid climate. Mean annual temperature at Phœnix is 69° F nnual precipitation is about 7 inches, according to Weather Bureau records. Winds are ally light.

[1] Publication authorized by the Director, U.S. Geological Survey.

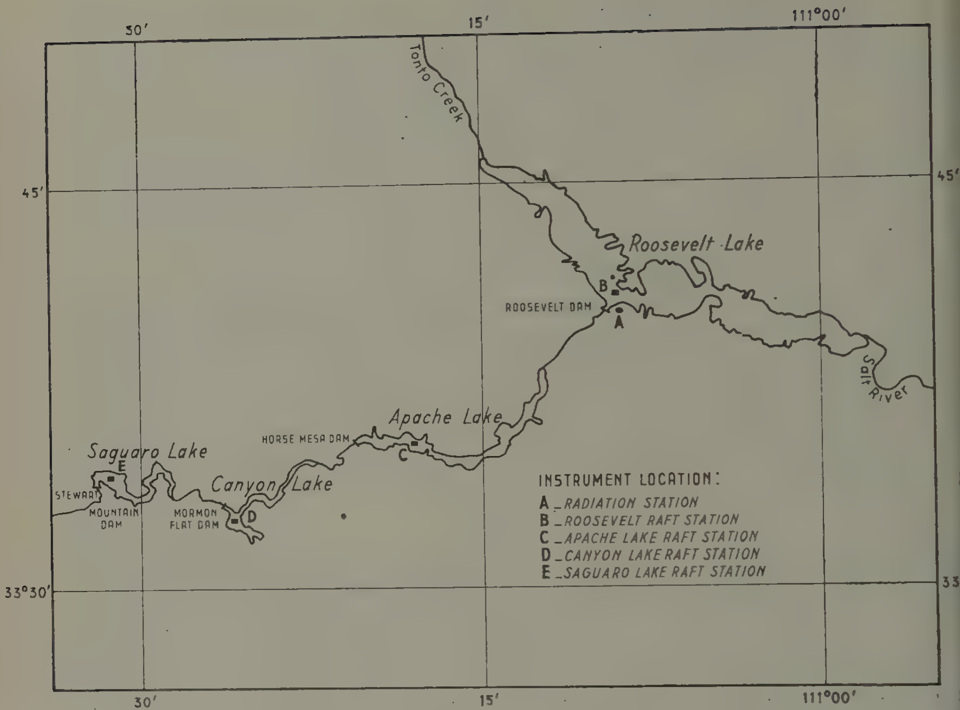

Fig. 1 — Map of Salt River reservoir system showing location of instruments

Evaporation from the reservoirs was determined by means of the energy-budget methc This method is an accounting of all energy entering and leaving a reservoir; the difference b tween the two is the amount utilized for evaporation, after allowing for the change in ener stored in the reservoir. The instruments needed to measure the various forms of energy we installed in March 1958. At a radiation station located near Roosevelt Dam records of so and atmospheric radiation and air and wet-bulb temperatures were obtained. Figure 2 sho the pyrheliometer and radiometer at that radiation station. A weekly thermograph to measu water-surface temperature, and a totalizing anemometer to record wind movement appro mately 6 feet above the water surface, were installed on a floating raft on each reservoir. Figur shows the Roosevelt raft with anemometer and recorder shelter. Thermal surveys of the res voirs were made at monthly intervals using a Whitney thermometer. The surveys made at t beginning and the end of the 1958 irrigation season are shown in figure 4. The data collected connection with the operation of the reservoir system were used to determine the advect energy term for each reservoir and lake. Koberg (1958), in the report on the Lake Mead studi described in detail how each term in the energy budget is evaluated. The computed evaporati from each reservoir using the energy-budget method is given in table 1. This table also gi evaporation from the Weather Bureau class A pan at Roosevelt Lake.

As shown in table 1, the evaporation rates differ considerably on an annual basis and ev more so on a monthly basis. For instance, on a monthly basis, evaporation from Roosev Lake in July was 12.1 inches and at Canyon Lake it was 4.4 inches, which is a difference 7.7 inches. On an annual basis, the evaporation from Roosevelt Lake was 69.9 inches and Canyon Lake it was 57.5 inches, which is a difference of 12.4 inches. These differences are sig

Fig. 2 — Radiation station at Roosevelt Dam with pyrheliometer and radiometer

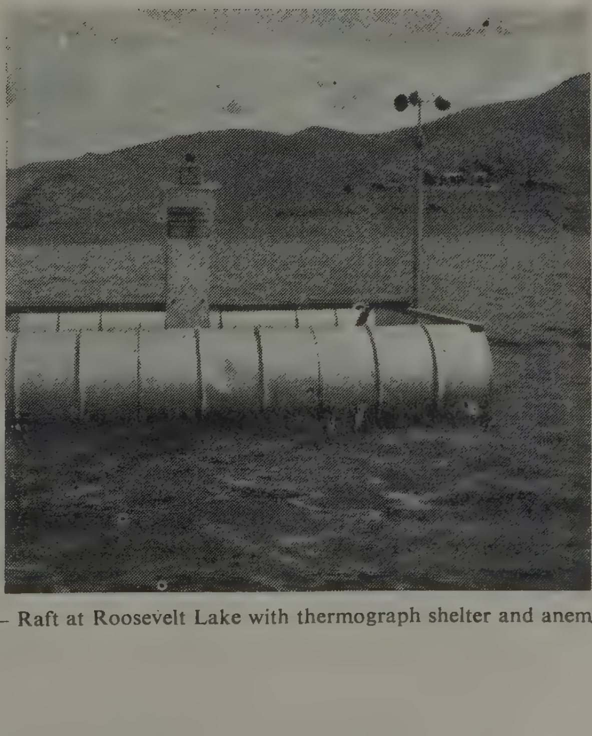

Fig. 3 — Raft at Roosevelt Lake with thermograph shelter and anemometer.

ficant especially if the reservoirs are under different management. In this case, the reaso[n]
for the differences should be known so that the apportioning of evaporation losses from t[he]
reservoirs could be made on an equitable basis.

TABLE 1

MONTHLY EVAPORATION ASMEASURED AT ROOSEVELT, APACHE, CANYON, AND SAGUARO LAK[ES] AND OBSERVED CLASS A PAN EVAPORATION AT ROOSEVELT LAKE.

Month	Roosevelt Lake		Apache Lake		Canyon Lake		Saguaro Lake		Class A p[an]
	Inches	Acre-ft	Inches	Acre-ft	Inches	Acre-ft	Inches	Acre-ft	Inches
April 1958	5.9	4,300	4.0	880	5.1	400	5.2	520	8.84
May	9.2	8,400	5.8	1,250	9.0	700	8.4	840	13.94
June	11.1	10,200	7.7	1,690	5.3	410	8.5	860	17.46
July	12.1	10,400	10.1	2,220	4.4	340	9.7	990	17.88
August	9.2	7,300	7.4	1,640	5.5	420	6.7	670	13.61
September	7.8	5,800	8.7	1,920	5.6	420	5.3	460	10.94
October	5.4	4,400	7.3	1,580	5.3	390	5.3	450	6.09
November	2.1	1,700	5.1	1,100	6.9	520	4.1	370	3.11
Decemb. 1958	.8	700	3.2	690	2.9	220	3.2	310	2.25
January 1959	1.0	800	3.1	680	1.9	150	2.0	200	2.62
February	1.3	1,100	2.2	480	1.3	100	2.1	220	3.12
March 1959	4.0	3,300	2.3	500	4.3	330	2.9	270	8.31
Total	69.9	58,400	66.9	14,630	57.5	4,400	63.4	6,160	108.17

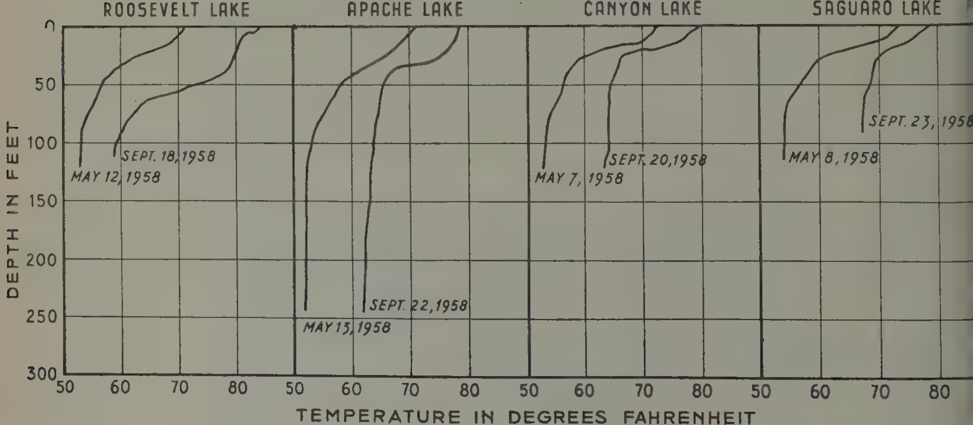

Fig. 4 — Temperature profiles of each reservoir on indicated date.

The operation of the reservoir system, to supply the irrigation needs, changed the tempera- structure of the reservoirs, which in turn affected the evaporation rates. The water was plied mainly from Roosevelt Lake. The monthly releases from the reservoirs are given in le 2. To supply 218,700 acre-feet of irrigation water from Roosevelt Lake at an average tem- ature of 58.2° F required at least this amount of water in storage before releases started ause the temperature of inflow averaged 75° F for the period. As shown by the thermal vey for Roosevelt Lake taken on May 12, 1958, (fig. 4) the water was at 58.2° F about feet below the surface and the volume of water below this depth was 197,000 acre-feet.

Before the releases were made, the temperature profiles in May of each reservoir were ilar as shown by figure 4. At the end of the irrigation season, the temperatures profiles in tember for the other reservoirs are considerably different from that of Roosevelt Lake. temperature profile for Roosevelt Lake in September extended over a greater range and hed a higher temperature than do the profiles for the other reservoirs, as shown in figure 4. profiles show that considerable mixing occurred in the other reservoirs as a result of the vement of water through them.

TABLE 2

MONTHLY RELEASES OF WATER AND ITS AVERAGE TEMPERATURE AT EACH RESERVOIR

e	Roosevelt Lake		Apache Lake		Canyon Lake		Saguaro Lake	
	acre-feet	°F	acre-feet	°F	acre-feet	°F	acre-feet	°F
	29,900	57	40,100	53	40,500	56	35,900	58
	57,100	56	55,000	54	54,400	60	47,100	64
	50,000	58	60,900	57	62,900	63	59,200	67
	56,800	60	67,800	61	70,400	65	74,300	69
	24,900	61	34,600	63	41,500	66	53,700	71
l	218,700		258,400		269,700		270,200	

The average temperatures of the monthly releases for the irrigation period are shown for reservoir in table 2. For Roosevelt Lake the temperature of outflow ranged from 56° to F, for Apache Lake from 53° to 63° F, for Canyon Lake from 56° to 66° F, and for Saguaro from 58° to 70° F. The average temperature of the water relaesed from Roosevelt Lake 58.2° F and from Apache, Canyon, and Saguaro Lakes it was 57.6° F, 62.3° F and 66.6° F ectively. No change in temperature could be detected as a result of the flow of water ugh the reach of channel from the dam to the reservoir below. Therefore, it is concluded all the rise in temperature occurred during passage of water through the reservoir. The n temperature is attributed to the mixing of the warmer water near the lake surface with older water that was brought in by inflow.

As the colder water released from Roosevelt Lake was warmed as it passed through most it had certain effects on evaporation rates. However, some of these effects were delayed after the irrigation period, so an analysis was made for a complete year. The period chosen

was April 1958 to March 1959. The method used for the analysis was described by Harbec and others (1959) in the report on Lake Colorado City. This method uses a combination mass-transfer and energy-budget concepts to compute the effect on evaporation and wat temperature resulting from addition or removal of energy in inflow and outflow. For eac reservoir, base evaporation was computed as the evaporation that would take place if it assumed that inflow equals outflow and the temperatures are equal, and that the resevoir energ storage at the beginning of the year was the same as that at the end of the year. Using the assumptions an analysis was made for each reservoir. The condition under which base evapo ration would take place is used only for comparison with the actual evaporation rates fro the reservoirs. In the Salt River system it would mean a hypothetical lake with very little inflo and outflow but having the topographic and meteorological characteristics of the reservoir

The analysis for Roosevelt Lake indicated that base evaporation for the period wa 64.1 inches. The measured evaporation (table 1) was 69.9 inches, which is 8 percent, or in term of volume, 4,800 acre-feet, more than the base evaporation. The reason for this increase is th the cold water released was replaced by warmer inflowing water and increased the energy stora above that which would occur under base conditions. For the reservoir to be at the avera temperature of 58.1°F at the end as at the beginning of the period, energy would have to dissipated at a higher rate than would occur under base conditions. This was obtained by i creasing evaporation, back radiation, and heat conducted to the air.

For Apache Lake the base evaporation rate for the period was computed to be 69.4 inche The measured evaporation was 66.9 inches (table 1), which is 4 percent, or in terms of volum 590 acre-feet less than the base evaporation. The reduction in evaporation was caused by t lake having more energy in storage at the end of the period than at the beginning. The avera lake temperature at the beginning of the period was 55.4°F and at the end it was 58.5°F, gain of 3.1 °F. This gain in energy stored resulted from radiant energy, as the net advect energy was approximately zero. Thus radiant energy normally available for evaporation w used to increase the energy stored in the lake.

The base evaporation rate for Canyon Lake was computed to be 67.1 inches for the perio The measured evaporation was 57.5 inches (table 1), which is 14 percent, or in terms of volum 740 acre-feet less than the base evaporation. The reduction was caused by cooling of wat near the surface as a result of the movement of water through the lake. This movement mix the warmer water at the surface with the cooler water at the bottom so that the temperatu of the outflow averaged 4°F more than of the inflow. This reduced the temperature at the wat surface which in turn reduced evaporation. Some of the energy that normally would have be available for evaporation was thus lost through the outflow.

The base evaporation rate for Saguaro Lake was computed to be 68.4 inches. The measur evaporation (table 1) was 63.4 inches, which is 7 percent, or in terms of volume, 490 acre-f less than the base evaporation. The cause of this reduction was the same as for Canyon Lak The difference in the percentage reduction was that the temperature of the outflow for Sagua Lake was 3°F more than that of the inflow instead of 4°F as for Canyon Lake. This sho that less energy was lost through the outflow for Saguaro Lake which then had more energy f evaporation.

The overall effect of different evaporation rates was that the total evaporation for t system was 2,980 acre-feet more than the base evaporation. Although releasing relatively co water from Roosevelt Reservoir resulted in greater evaporation there, amounting to 4,800 ac feet, the cold water released made the evaporation from the three downstream lakes less 1,820 acre-feet than what would have occurred for base conditions.

Generally, a run-of-the-river type reservoir would have a lower evaporation rate than large reservoir where the inflow during the summer is only a small percentage of the stora The difference in rates depends on what depth releases are made from the large reservoir. T lower evaporation rate for the run-of-the-river type reservoir is a result of the mixing caus by the movement of water through the reservoir. If the mixing could keep the water isotherm in the reservoirs, the greatest reduction in the evaporation rate would then be obtained. F

ery deep runof-the-river type reservoir, this is very difficult to obtain as evidenced by Apache ke. In this case a deep run-of-the-river type reservoir may have the same evaporation rate the large storage reservoir.

Reservoir evaporation is often determined by pan evaporation and a coefficient. The Lake fner studies (Kohler, 1954) show that this coefficient varies during the year. The variation his coefficient for the standard class A pan at Roosevelt Lake are shown in table 3.Also wn are coefficients for the other reservoirs using the same pan. Pan coefficients for monthly poration from reservoirs in the system ranged from 0.25 to 2.14. For annual evaporation coefficients ranged from 0.53 to 0.65. If the coefficients for annual evaporation are computed each reservoir using the base evaporation, the ratios range from 0.59 to 0.64, which is in eement with pan coefficients recommended by some hydrologists for use in the arid West.

Engineers and hydrologists who estimate reservoir evaporation from pan records should aware that large amounts of heat usually available for evaporation are sometimes used for er heating instead. Also, they should be aware that a reservoir regularly releasing cold er will have a higher evaporation rate than would be expected. At Lake Mead, the tempera-e of the outflowing water is normally much lower than that of the inflowing water. About f of this inflow energy not balanced by outflow energy is being utilized to increase the eva-ation rate. Harbeck (1958) computed that if it were possible to skim the warm water from lake surface instead of releasing cold water from the depths of the reservoir, evaporation uld be decreased 8 percent. Kohler and others (1955) in their studies on evaporation from s and lakes, have developed techniques to adjust lake evaporation where inflow energy is balanced by outflow energy.

TABLE 3

MMARY OF CLASS A PAN COEFFICIENTS FOR MONTHLY AND ANNUAL EVAPORATION FROM ROOSEVELT RESERVOIR, APACHE LAKE, CANYON LAKE, AND SAGUARO LAKE RESERVOIRS.

Month	Roosevelt Lake	Apache Lake	Canyon Lake	Saguaro Lake
8				
ril	0.67	0.45	0.58	0.59
y	.66	.42	.65	.60
e	.63	.44	.30	.49
y	.68	.56	.25	.54
gust	.68	.54	.40	.49
tember	.73	.80	.51	.49
ober	.88	1.20	.87	.85
vember	.68	1.65	2.10	1.32
cember	.36	2.14	1.18	1.45
9				
uary	.38	1.19	.65	.77
oruary	.42	.71	.36	.68
rch	.48	.28	.46	.35
nual	.65	.62	.53	.59

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CHEMICAL EQUILIBRIUM DIAGRAMS FOR GROUND-WATER SYSTEMS

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graphiques de l'équilibre chimique pour les systèmes des eaux souterrainnes.

JMÉ

L'équilibre chimique de l'eau au contact avec la calcite est exprimée par un pH — qua-
age superposé sur un log-log graphique donnant les activités du bicarbonate contre les du calcium. La solubilité du fer ferreu et les minéraux de la phase solide, qui seraient stable une solution contenant les activités de 10 per mille du sulfate et 100 per mille du bicar-
ate, ou les espèces alliées, est exprimée par un graphique donnant relation stabilité —
np avec pH sur l'abscisse, et le potentiel de redox sur l'ordonnée.

Les graphiques peuvent servir pour indiquer si l'eau injectée dans les puits de recharge herait des précipitations, qui pourraient obstruer la couche portante, et ils ont aussi d'autre ications dans les études de la chimie de l'eau dans la nature.

RACT

Chemical equilibrium in water in contact with calcite is expressed by means of a pH grid lay on a log-log plot of activities of bicarbonate vs. calcium ions. Solubility of ferrous iron the solid-phase minerals that would be stable in a solution containing activities of 10 ppm ulfate and 100 ppm of bicarbonate or related species is expressed by means of a stability-diagram with pH as abscissa and redox potential as ordinate.

The diagrams can be used to tell whether water injected in recharge wells may form pre-ates that may plug the aquifer and have other uses in studies of natural water chemistry.

URAL WATER SYSTEMS

The factors affecting the chemical composition of natural waters are so complex as to be aying. Because of this the theoretical chemical concepts, developed many years ago from y of dilute aqueous solutions, have been used very little in hydrology. It has seemed that simplification needed to apply chemical thermodynamics to natural waters would be so nsive the results would have no practical value. However, in recent years research has shown the chemical behavior of some of the constituents of natural water actually does coincide er closely with what might be predicted theoretically.

Pourbaix (1949) developed a graphical procedure for describing the chemical behavior of in dilute solution in relation to pH and redox potential. This technique has been used nsively by investigators in geochemical studies in the United States in recent years, notably . M. Garrels (1960) and his co-workers (Huber and Garrels, 1953) to explain deposition etallic ores.

The chemistry of iron in natural water has recently been studied by the U. S. Geological ey (Hem and Cropper, 1959, and Hem, 1960 a and b) using, in part, Pourbaix's procedure. agreement between theoretical and actual behavior of this constituent has been abundantly ied. Most reactions involving iron reach equilibrium rapidly and are well suited to study by ns of chemical thermodynamics.

A large amount of work has been done on the chemical behavior of carbonates. Some o the conclusions indicated by the literature are: (1) Reactions by which calcite is dissolved o precipitated are rapid enough to require consideration and control in distribution of water sup plies (Fair and Geyer, 1954, p. 647-650); (2) comparisons of the actual pH of a solution and th pH calculated for that solution assuming chemical equilibrium with respect to calcite provid a useful index as to future behavior of the solution when brought into contact with solidpha calcite (Langelier, 1936); (3) water in pores of a limestone is normally saturated with respe to calcite, (Weyl, 1958). Probably this last conclusion can be extended to any rock in whic calcite is present in important quantities.

In its simplest terms, assuming a temperature of 25°C and a pressure of 1 atmosphere, th equilibritum for calcite in water is:

$$CaCO_3\,c. + H^{+}aq. \rightleftharpoons HCO_3^{-}aq. + Ca^{+2}aq.\ (*)$$

This system does not contain a gas phase and is likely to be the usual condition below the wat table. The equilibrium constant K_{eq} can be computed from the relation

$$\Delta F^{o} = -RT \ln K_{eq}$$

where ΔF^{o} is the net change in standard free energy when the reaction goes from left to righ R is the gas constant, T is the temperature in degrees Kelvin, and ln K_{eq} is the Napierian (natural) logarithm of the equilibrium constant. Standard free energy values for calcite and t ions involved are available in texts such as that of Latimer (1952). At 25° C, the equilibrium p for a water may be computed from the mass-action law, assuming activity of calcite to be unit

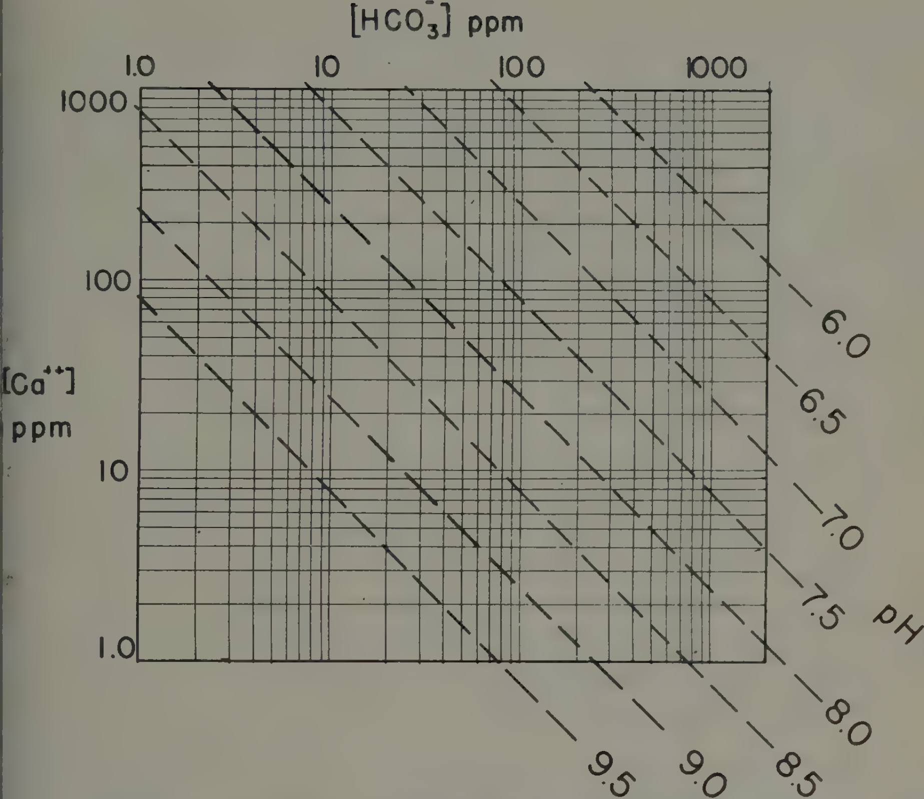
$$pH\,eq = -\log \frac{[Ca^{+2}]\,[HCO_3^{-}]}{K_{eq}}$$

The quantities in square brackets are thermodynamic concentrations, or activities of dissolv ions and are computed from the concentrations reported in chemical analyses by means of t Debye-Hückel limiting law. Procedures for making these computations are given by Klotz (195 and an adaptation of these procedures with graphical aids developed by the writer (Hem, 196 is particularly adapted for use with data from standard water analyses.

Figure 1 is a graph showing the equilibrium pH computed from the above equation for a solution in contact with calcite in relation to dissolved calcium and bicarbonate activities. T difference between concentrations of calcium and bicarbonate reported in analyses and effecti concentrations, or activities may be substantial. In general, the activity of calcium in a soluti whose total dissolved solids concentration is near 400 ppm is about 70 percent of the measu concentration of calcium. The bicarbonate activity in such a solution would be about 90 perc of the measured concentration. In a water whose total dissolved solids is about 4000 ppm, t calcium activity is about 40 percent of the measured calcium concentration and bicarbon activity is about 75 percent of the measured bicarbonate concentration. For waters that cont more than 5000 ppm dissolved solids relationships of measured concentrations to activit are less well defined.

Figure 1 represents conditions at 25° C. The solubility of calcite decreases somewhat increased temperature (Weyl, 1959), and temperature deviations from 25° C. also affect activity corrections and the pH measurement. Temperature corrections probably are not need in the practical application of the diagram to waters which are within 15° or so of 25° C. Ho ever, it should be remembered that the results obtained in this way are approximations a that in a rigorous application of the principles used one must use more exacting metho Because the pH of solutions may change in stored samples, measurements of this property sho be made in the field when water samples are collected.

(*) The symbol « c. » represents the crystalline solid state of the substance and the symbol « a represents the dissolved form.



1 — Equilibrium pH in relation to calcium and bicarbonate activities in solutions in contact with calcite. Total pressure 1 atm., temperature 25°C.

mistry of Iron

Laboratory and theoretical studies (Huber and Garrels, 1953, and Hem and Cropper, 1959) vell as practical experience with the behavior of natural water have shown that equilibrium n respect to some of the commonly found sedimentary iron minerals is to be expected in und water.

The kinds of equilibria that are most important in iron chemistry include (1) hydrolysis, n or without oxidation or reduction, for example

$$Fe^{+3}_{aq} + H_2O \rightleftharpoons FeOH^{+2}_{aq} + H^+ \, aq$$

solution and precipitation reactions involving anions other than OH^-, for example

$$FeCO_3 \, c. + H^+_{aq} \rightleftharpoons Fe^{+2}_{aq} + HCO_3^- \, aq$$

(3) redox equilibria such as

$$Fe(OH)_{3}c + 3H^+_{aq} + e \rightleftharpoons Fe^{+2}_{aq} + 3H_2O$$

symbol "e" represents the unit negative electrical charge gained by each ion of iron redu-). Conditions at equilibrium in a system involving water, dissolved ions, and iron-bearing

minerals, such as ferric hydroxide (or hydrated ferric oxide), siderite, or the sulfide minera
such as pyrite can be evaluated by means of equilibrium constants, along with relationships i
volving the redox potential.

The redox potential of a solution, represented by the symbol Eh, is a measure of the relati
intensity of oxidizing or reducing conditions in a system. It is expressed in volts and at equi
brium is related to the proportions of oxidized and reduced forms present. The relationshi
can be expressed by standard equations of chemical thermodynamics.

The standard potential, E°, of a redox system is the potential under standard conditio
when unit activities of participating substances are present. It is related to standard free ener
change in a reaction by the equation

$$\Delta F^{o} = -nfE^{o}$$

where n is the number of unit negative charges shown in the redox reaction and f is the Farad

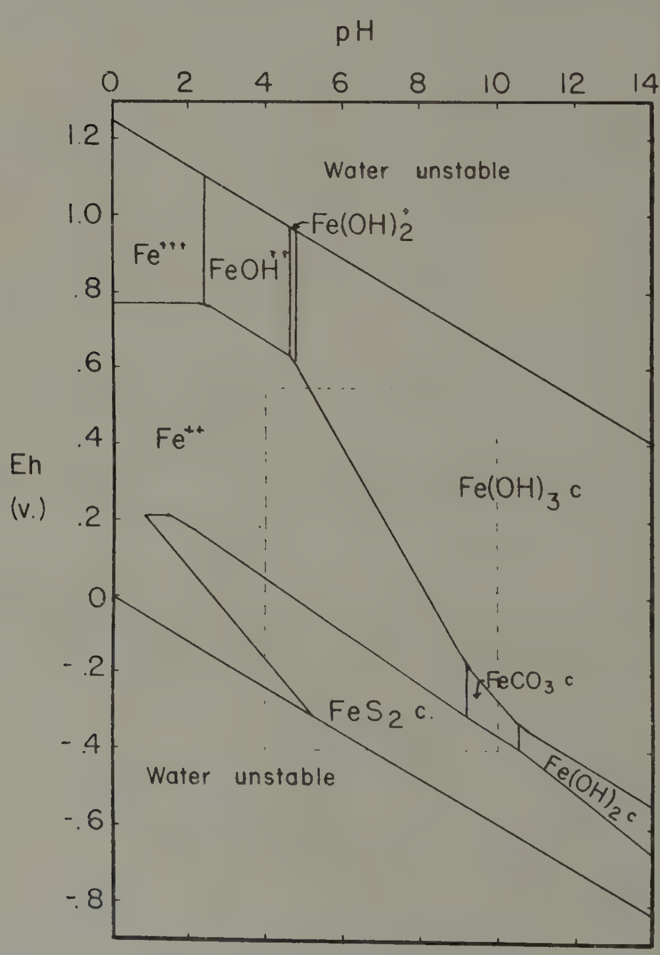


Fig. 2 — Stability fields for aqueous system in which maximum dissolved activities are : Iron as Fe 01 p
carbonate species as HCO_3 100 ppm, sulfur species as SO_4^{--} 10 ppm. 1 atm. pressure, 25°C.

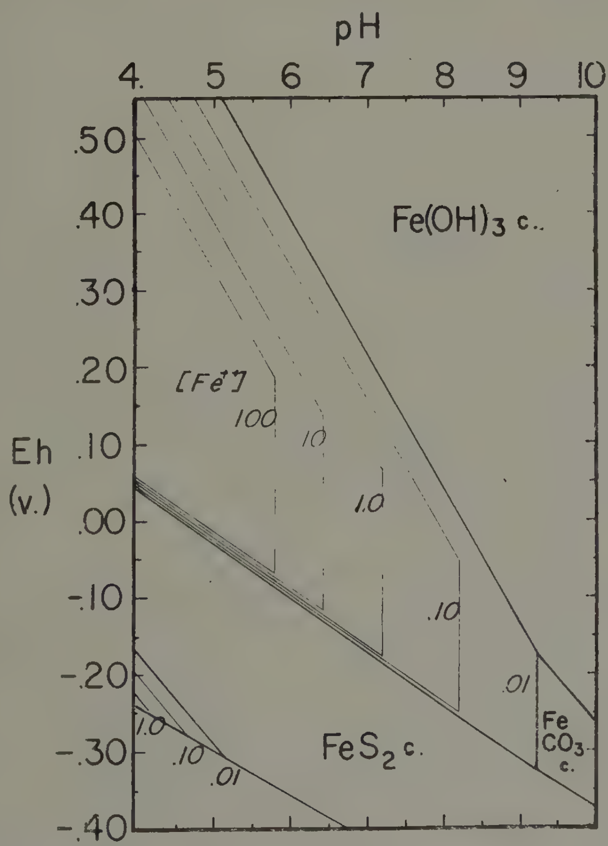
tant, in units that give a potential in volts. The redox potential in systems not under stan- conditions is given by the Nernst equation:

$$E = E^{o} + \frac{RT}{nf} \ln \frac{[\text{oxidized species}]}{[\text{reduced species}]}$$

algebraic signs of Eh and E^{o} are arbitrarily assigned. In Pourbaix's work and in geoche- l literature, increasingly oxidizing conditions are represented by increasingly ive potential values.

Figure 2 is a stability-field or Eh - pH diagram of a hypothetical system containing dissolved and a constant activity of ions derived from dissolved carbon dioxide, such as bicarbonate, of ions derived from sulfur, such as sulfate. The boundaries were computed by equilibrium lations, and show the conditions of Eh and pH at which the common ionic species of iron d be stable. Stability fields for solids show those areas where activity of iron in solution d be less than 0.01 ppm. The nature of the solid formed depends on the form and amount ions present, as well as on Eh and pH.

The field of stability shown for pyrite entails oxidation and reduction of sulfur, and use these reactions are slow they may not be at equilibrium in natural water systems.



3 — Dissolved iron in relation to pH and Eh. Carbonate species as HCO_3 = 100 ppm, sulfur species as SO_4^{--} = 10 ppm.

Otherwise, however, the diagram probably represents the factors controlling iron solubili with reasonable accuracy.

Figure 3 is an enlargement of the area of figure 2 between pH 4 and 10 and between E + .55 volts and —.40 volts. This covers the usual range of groundwater systems. On the diagra are shown the corresponding positions of the solid phase boundaries for the indicated ir activities from 0.01 ppm to 100 ppm. In effect, these lines represent iron solubility contours fo the system in consideration, and can be used to explain and predict the behavior of iron disso ved in ground water.

In that part of the field where iron solubility lines are parallel to the Fe $(OH)_3$c. boundar the system would be in equilibrium with this solid and dissolved iron is a function of Eh an pH. Where the lines are vertical, the dissolved iron would be in equilibrium with siderite (fe rous carbonate) and dissolved iron is a function of pH and total available dissolved carbona species. If pyrite is present, oxidation of the sulfur to SO_4^{-2}, may occur, releasing ferrous-iro in the process, although the equilibrium may not be strictly applicable here. At a very low p and Eh the pyrite may be reduced to give H_2S and ferrous iron.

Measurement of Eh in natural waters is subject to difficulties. Generally the amounts the dissolved ions present which set the Eh of a ground-water system are small, and even short contact of the solution with air introduces enough oxygen so that the measurement indicative of the effect of dissolved oxygen and not of the system that controlled the Eh unde ground out of contact with air. In some instances, as where measuring electrodes can be insert in the discharge pipe of a flowing well, a dependable value of Eh can be fairly easily obtaine William Back and Ivan Barnes (written communication) in recent research in the U.S. Geo gical Survey have developed measuring techniques that are useful in more difficult situatio and reliable and more extensive information on the Eh of ground waters should eventua result.

If complicating factors that may sometimes occur, such as the formation of chemical co plexes, are ignored it is evident from figure 3 that any water containing 1.0 ppm of iron or mo is going to retain that amount of iron in solution only at low pH, intermediate Eh, or bot Measurement of pH is generally easier than Eh, and from figure 3, the iron content and the p of a ground water, the Eh can be estimated, provided one knows which solid form is involv in the equilibrium.

Over the entire area of figure 3 iron in solution is controlled by four somewhat interrelat variables, Eh, pH, $[HCO_3]$ and $[SO_4^{2}]$. If a water contains 1 ppm of iron at pH 7, and the Eh +. 10 volt the dominant solid phase form of iron present is ferric hydroxide, when bicarbona activity does not exceed 100 ppm and sulfate activity does not exceed 10 ppm. Siderite co not be the dominant solid phase at this level of bicarbonate activity, at pH 7 unless the were lower. If the dominant solid is pyrite the equilibrium Eh would be about -0.16 volt, b this condition is less likely than the other possibilities.

If the activity of bicarbonate species is decreased by a factor of 10, the vertical iron co centration lines are shifted to the right by 1 pH unit and the stability field for siderite at 0. ppm activity of iron disappears. At low levels of bicarbonate, therefore, the influence of c bonate equilibria on iron content is not very important at pH 7. If the bicarbonate activ were increased to 1,000 ppm, the presence of 1 ppm Fe^{++} at pH 7 would not be possible equilibrium. The pH would have to be lower (≤ 6.2) to permit 1 ppm of iron to be retained solution.

Changes in sulfur activity have only a minor effect on the position of pyrite bounda Changes of a factor of 10 in total sulfur species move the boundary of the pyrite field less th 0.01 volt.

Huber (1958) has discussed some aspects of iron equilibria in systems containing carbon and sulfur.

The chemical relationships expressed in figures 1-3 are useful in studies of chemistry of nd waters in relation to geology or hydrology. Changes in carbonate equilibria are involved ocesses of calcite cementation of sandstones and the deposition of calcite at points where r enters a pumped well. Diagrams such as figures 2 and 3 aid in predicting redox potentials ound water environments. Both the carbonate and iron equilibria may be upset when nd waters of different composition are mixed. An important application of the diagrams fore arises in the artificial recharge of aquifers.

icial Recharge

Published literature on artificial recharge through 1954 has been annotated by Todd (1959). pleted and currently operating experiments for introducing recharge through wells have led a number of factors that affect the rate at which wells will take water. Generally many s of recharge and discharge of the groundwater reservoir will occur as time passes. The m must be capable of operating for a long time without any important loss of transmissi- y of the aquifer. In the petroleum industry water injection has been used for maintaining ures in oil fields, and to increase oil recovery. Some of the problems encountered in these eld operations are similar to those of artificial recharge. However, a low rate of injection ed in oil recovery operations, and their success is evaluated in a different way than the ss of a recharge project.

If the recharge water contains suspended solids, the well into which the water is introduced apidly become clogged by deposition of these solids unless the passages through which the r moves are very large. Clarification of such a water is generally necessary (Calif. state r Pollution Control Board, 1954, p. 21).

Air bubbles in the injected water may lodge in the aquifer and lower the rate at which r can be recharged (Sniegocki, R.T., written communication 1958).

Microbiota in the recharge water may become established in the well, and their growth result in slime deposits that interfere with the movement of water into the aquifer. In ex- ents in California, Laverty (1952) noted that a large and continuing dose of chlorine con- d these microorganisms.

If the introduced water contains a proportion of monovalent to divalent cations that dif- greatly from that in the water native to the aquifer, cation exchange with clay minerals nt in the aquifer will take place. The dispersal or flocculation of clays brought about by xchange process may alter the transmissibility of the aquifer. Literature of artificial re- ge does not show that this effect is common, but Hughes and Pfister (1947) reported swelling ays sometimes results from injection of water in secondary recovery of oil. They suggested se of brines to avoid loss of transmissibility.

Chemical precipitation of carbonates and of iron compounds evidently is a major problem. onate precipitation was reported by Banks (1953) in wells at Manhattan Beach, California. oxide precipitation commonly occurs during recharge operations and has been reported at d Prairie, Arkansas (personal communication, Sniegocki, R.T.), Camp Peary, Virginia erstrom, D.J., 1947), and in the Netherlands (Krul and Liefrinck, 1946), to name a few of eferences in published literature.

When recharge is brought about by spreading water at the land surface or by related tech- es, the soil or other materials through which the water passes acts as a filter and chemical itioner in the same way as for naturally occurring recharge. Hence, the difficulties enu- ited for introduction of recharge through wells are largely avoided. Other kinds of problems the surface-spreading techniques, to be sure, but they are not usually the ones considered

The compatibility of native ground water with a water proposed for injection can be eva- d by means of figure 1. If the water to be injected is substantially supersaturated with

respect to calcite and the native water has a pH the same as or higher than the water to be in-jected, calcium carbonate will be precipitated in the injection well and in the aquifer an movement of water will be impaired. Even though the amount precipitated per unit volume c water might be small, the large volumes of water and the recycling of the system inherent in full-scale recharge program might make such deposits a major threat to practicabilit Although many surface waters are unsaturated with respect to calcite, supersaturatio because of loss of dissolved carbon dioxide is common, especially in water that has been store in reservoirs. If necessary the pH of injected water could be lowered by introducing CO_2 or b other means, so that the risk of calcite precipitation could be avoided.

With the stability field diagram, analyses of the native water and water proposed for in-jection and some knowledge as to iron minerals present in the aquifer, proposed recharge ex-periments can be evaluated for possible iron difficulties. Under some conditions excessiv amounts of iron might be dissolved by the introduced water, but more commonly plugging c well and aquifer by precipitates of iron constitute the major difficulty.

If the proposed recharge water contains iron, any contact with air is likely to cause ferr hydroxide to precipitate. The Eh of aerated water will generally range from about 0.35 to 0.4 volt. Figure 3 shows that 0.01 ppm of iron can remain in solution at Eh 0.45 volt only if pH less than 5.7. Hence, ironbearing recharge water is almost certain to deposit iron in the recharg well. Closed systems where ground water containing iron is withdrawn for cooling purpos and returned through an adjacent well may be expected to operate successfully only if they a sealed from possible contact of water with air.

If the aquifer to be recharged contains ironbearing water and iron minerals, the addition or replacement of this water with aerated recharge water will precipitate ferric hydroxide whe the two waters contact each other or are mixed together. The places where precipitation w occur and the amount of iron deposited is somewhat difficult to predict because it depends c the way the injected recharge water moves through the saturated or dewatered parts of th aquifer.

If the aquifer contains siderite the aerated water will tend to convert this mineral to ferr hydroxide, although the conversion may occur only on the surface of the mineral crystals. pyrite is present, however, the oxidizing injected water may attack it, dissolve considerab amounts of iron and probably redeposit the iron as ferric hydroxide in the aquifer along th direction of movement of the injected water front. Some of the water pumped back out of suc a system also could be rather high in dissolved iron.

Where sulfur-reducing bacteria are present, iron in the recharge water could be deposit as sulfide. Alcorn (1943) noted this effect in oil recovery operations.

Remedial measures may sometimes be feasible, but it seems very likely that highly iro bearing ground-water systems cannot be successfully recharged by injection of surface wat through wells. Although the need for chlorination to overcome biological problems in co ditioning recharge water seems established, a water that contains a residual of dissolved chlori has an Eh far above that of aerated water, and problems resulting from iron precipitation fro such a water are likely to be severe if the system to which the chlorine-bearing water is add contains pyrite or much iron in solution.

The need for moving large volumes of water in a large-scale project for recharge throu wells magnifies the importance of relatively small concentrations of potentially troubleso substances, such as iron. Large-scale recharge of aquifers differs from oil-field operatio for example, because of the very large volumes of water required in recharge and the cyc removal of the water for use, to be replaced by further recharge.

The techniques for study of chemical data described in this paper are believed to hav well established validity and should be particularly useful where ground-water recharge injection through wells is planned. The diagrams also are useful in studying other aspects natural water chemistry.

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VARIATION IN SURFACE ELEVATION OF THE NISQUALLY GLACIER MT. RAINIER, WASHINGTON

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ABSTRACT

Variation in surface elevations of the Nisqually Glacier has been recorded since 1942 the annual measurement of three profiles across the glacier, designated as nos. 1, 2, and located 0.5, 1.0, and 1.7 miles respectively from the terminus, at approximate mean elevatio of 5,250, 6,000, and 6,800 feet. A fourth profile, 2-A, located 1.4 miles from the terminus at approximate mean elevation of 6,450 was measured from 1948 to 1954. These profiles cross t glacier approximately normal to the direction of flow. Additional data are available fr measurements made at profiles no. 1 and no. 2 in 1931, 1932 and 1941. The results of the measurements show that a wave or surge has been moving down the glacier.

The mean elevation at profile no. 3 began to increase in 1945 and continued through 19 when it was 83 feet higher than in 1944. The general trend from 1952 to 1959 has been a decrea in elevation with a net change of 30 feet since 1951. The surface elevation at profile no. 2 co tinued to decrease through 1948, but began to increase in 1949 and continued to do so throu 1957 in which year the mean elevation was 102 feet higher than in 1948. The wave became app rent at profile no. 1 in 1954 or 9 years after it first became evident at profile no. 3. The me elevation has continued to increase and in 1959 was 70 feet higher than in 1954. The increase surface elevation has been accompanied by a pronounced increase in rate of movement of t glacier.

A program of mapping the Nisqually Glacier at 5 year intervals was initiated by Lewell Evans, Superintendent, Tacoma City Light Department and G. L. Parker, District Engine U. S. Geological Survey in 1931 as a means of recording changes in the glacier. The 5 year ma ping program has been carried out. A map of the glacier in 1951 and 1956 has recently be published. In 1931, along with setting markers for the determination of movement, two profi were measured across the glacier, referred to in this paper as profile no.1 and no. 2. These located 0.5 and 1.0 miles respectively from the terminus (1956 position). These profiles w remeasured in 1932 and 1933 after which measurements were discontinued. The author, 1941, while mapping the glacier resumed measurement of these two profiles. In 1942 a th profile, no.3, and in 1948 a fourth, no. 2-A, was established. These are located 1.7 and 1.4 mi respectively upglacier from the terminus. The location of the four profiles is shown in the in on figure 1. The measurements of these profiles have provided a record of pronounced variati in the surface elevation of the glacier and have also provided a record of a wave or surge t has been moving down the glacier. This paper will be devoted primarily to a description of growth and movement of this wave. Before starting this discussion, a brief description of glacier is in order.

The Nisqually Glacier is located on the southwest flank of Mt. Rainier. It is one of o 20 glaciers on the mountain and one of 6 that radiate from the summit of the mount like the arms of a starfish. From the summit of the mountain to the terminus (1956 positi it has a length of 4½ miles, in which distance it has a range in elevation of 10,000 feet. terminus, as shown on the 1956 map, was at an elevation of 4,400 feet. It is a valley glacier its greatest width does not exceed one-half mile. The Wilson Glacier, a cirque glacier with upper limits at about an elevation of 10,000 feet, is tributary to the Nisqually Glacier on

ıt or west side, between the elevations of 7,200 and 8,600 feet. The observations on the Nis-ılly Glacier on which this paper is based are downglacier from the confluence with the Wilson ıcier. The Nisqually Glacier, as measured on the 1956 map (and partly on the map of Mt. ınier National Park) has an area of 1070 acres and the Wilson Glacier an ara of 340 acres or ɔtal of 1410 acres, 2.2 square miles. The distribution of area in relation to elevation istabulated ɔw.

Section	Area, Acres	Percent of Total	Cumulative Percentage
ɔve 12,000	160	11.4	11.4
)00 to 12,000	195	13.8	25.2
)0 to 10,000	450	31.8	57.0
)0 to 8,000	460	32.6	89.6
)0 to 6,000	145	10.4	100.0
Total	1410		

The above figures show that about one-fourth of the area is above 10,000 and over one-half ve 8,000 feet in elevation. The median elevation is approximately 8,400 feet.

As previously mentioned, two profile lines were established in 1931, a third one in 1942 a fourth one in 1948. The results of the measurements of these four profiles will be sum-ızed in the following paragraphs, starting with the uppermost and moving downglacier. files for selected years are shown graphically in figure 1.

The uppermost profile, no. 3, is located 1.7 miles from the terminus at an approximate ın elevation of 6,800 feet, a short distance below the confluence of the Wilson and Nisqually ciers. As reported in a letter, dated June 7, 1943 to Francois Matthes, who was then Chair-ı, Committee on Glaciers, American Geophysical Union,

> «This profile was established with the thought in mind that changes observed heremight indicate future changes to be expected on the lower glacier and also give some information on the relation between changes in the various altitude zones».

data obtained at this profile in subsequent years has proved to be far more important than envisioned at the time.

Profile no.3 was first measured on August 21, 1942. The first remeasurement in 1943 showed ıverage increase in elevation of approximately 5 feet. The lowest point of the profile was the ıe elevation in both years, and was near the right or west side. The 1944 measurement showed ecrease in elevation of 8 feet. This measurement, however, was one month later than the 1943 ısurement. If it had been made at the same time of year, the difference would have probably ı about 4 or 5 feet instead of 8 feet. The surface as recorded by the 1944 measurements was lowest observed during the observations that have been made at this location. Successive ısurements at this profile showed a rise each year through 1951. Measurements were not le in 1950 as the east edge of the glacier had raised to such an extent that the reference point covered with ice. In reviewing the changes from year to year, the most significant difference ed was the pronounced filling in near the right side during the two year period 1949 to 1951. shown on figure 1, the filling in along this section of the profile was well over 100 feet during 1949-51 interval. Much of the ice that filled in this area very likely originated from the Wilson cier, as reference to the map shows that an extension of the center line of the Wilson Glacier ıld come through this section of the profile. The surface, as measured in 1951, was at the ıest point recorded in the current series of observations. Reference to photographs indicates the surface in 1950 may have been equally as high or even higher. In the absence

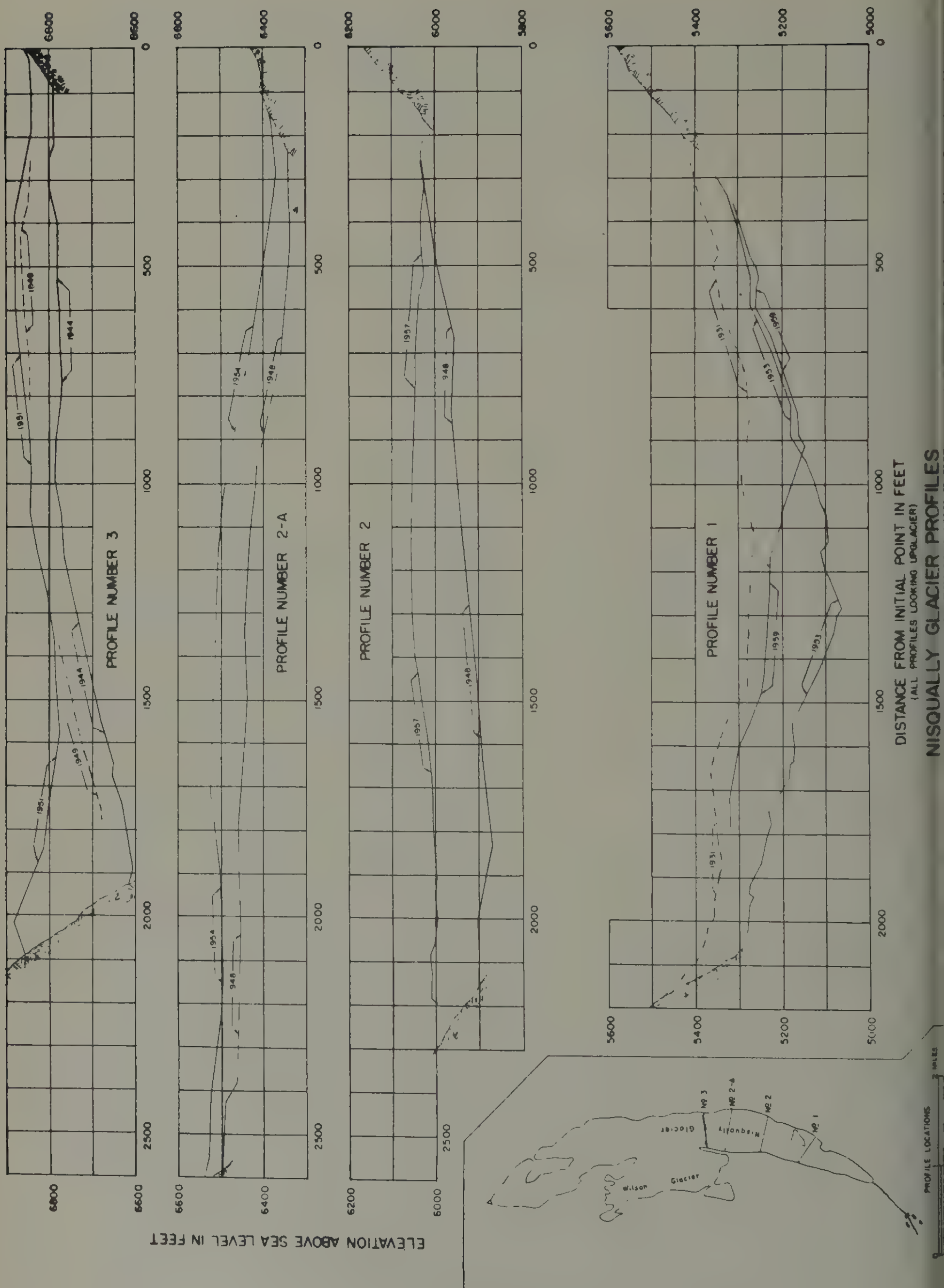

NISQUALLY GLACIER PROFILES
DISTANCE FROM INITIAL POINT IN FEET
(ALL PROFILES LOOKING UPGLACIER)
ELEVATION ABOVE SEA LEVEL IN FEET
PROFILE NUMBER 3
PROFILE NUMBER 2-A
PROFILE NUMBER 2
PROFILE NUMBER 1
PROFILE LOCATIONS
Wilson Glacier
Nisqually Glacier

Fig. 1

definite information to the contrary, 1951 is therefore being considered as the hest year. The results since 1951 have fluctuated. Both 1952 and 1953 showed a decrease h year whereas 1954 showed a slight increase; 1955 was a year of slight decrease, and 1956 ronounced increase; 1957 and 1958 both showed marked decreases with an increase in 1959. e largest increase, 21 feet, was between the years 1955 and 1956, and the most pronounced rease, 29 feet, between 1957 and 1958. The mean elevation in 1951 was 83 feet higher than in 4 and in 1959 was 30 feet lower than in 1951 or 53 feet higher than the low of 1944. The ximum difference between 1944 and 1951 was 225 feet.

In view of the continuing rise in the surface elevation noted at profile no. 3, an additional file, located 1.4 miles from the terminus roughly mid-way between no. 2 and no. 3, designated no. 2-A, was established in 1948. It is at an approximate mean elevation of 6450. This was asured annually, except 1950, from 1948 through 1954; and only partially measured in 1950 1 1955 as the glacier was so badly broken up that it was impracticable to cross the glacier on profile alignment. No further attempts have been made to measure this profile since 1955. ring the six years of available record, there was a net increase in the average elevation of 56 ; 51 feet occurring during the three year interval 1948 to 1951. The years 1952 and 1953 both wed a slight decrease with 1954 showing an increase which more than offset the loss in 1952 1 1953.

Profile no. 2 is located 1.0 miles from the terminus at an approximate mean elevation of 00 feet. This profile was first measured in 1931 in connection with the establishment of a line markers for measuring movement. It was remeasured in 1932 and 1933 after which measure-nts were discontinued. When remeasured in 1932, it showed an average increase of 18 feet. ther comparable data is not available until 1936, in which year a map was made of the lower tion of the glacier. A profile, as developed from this map, shows an increase of 23 feet since 2. Measurements of this profile were resumed in 1941, in which year the mean elevation was feet lower than in 1936. Whether or not a higher elevation was reached between 1932 and 1 than shown on the 1936 map is not known. Measurements at this profile showed a con-uous annual decrease in elevation through 1948, total for the seven year period 1941-1948 ounting to 51 feet. The increasing thickness of the ice or increased surface elevation noted at file no. 3 since 1945 became apparent at profile no. 2 in 1949. In that year the west or right f of the glacier showed an appreciable increase in elevation whereas the left half continued lecrease. By 1950 the entire profile showed an increase in elevation. This increase continued h year through 1957, at which time the mean elevation for the entire profile was 102 feet her than in 1948 with a maximum difference of 135 feet. The surface in 1958 was 9 feet lower n in 1957 and in 1959 was essentially the same as in 1958. It would appear, therefore, that crest of the wave reached profile no. 2 in 1957; and the trend since then has been a decrease elevation. The 1960 observations will probably show a more pronounced decrease at this ation.

Profile no. 1, located 0.5 miles from the terminus at an approximate mean elevation of 0 feet, was also first measured in 1931 in connection with setting a line of markers to deter-ne rates of movement. A measurement in 1932 showed a decrease in elevation of 4 feet. No her comparable measurements were made until 1941. A profile as developed from the 1936 p, showed a decrease of 9 feet since 1931. It is of interest to note that during this same five r interval, 1931-36, there was an increase of 41 feet in mean elevation at profile no.2. Measu-ents at profile no. 1 in 1941 showed that during the five year interval from 1936 to 1941 there an average decrease in elevation of 37 feet. If the rise in surface elevation at profile no. 2 ween 1931 and 1936 extended down to profile no. 1, it occurred sometime between 1936 and 1. It seems doubtful that any rise did occur. The surface along this profile continued to lower levation each year through 1954, except for a short section near the right edge which showed ght increase since 1953 but the mean elevation for the entire profile decreased. The net change n 1931 to 1954 amounted to an average of 136 feet, and since 1941 an average of 90 feet. change in elevation along this profile was much less pronounced in the left or east one-third n in the right or west two-thirds. Although the decrease in average elevation for the period

1931 to 1954 was 136 feet, the maximum difference as shown by figure 1 exceeded 200 feet. T first indication of an increase in surface elevation at this profile appeared in 1954 when a porti near the right edge showed an increase, whereas most of the rest of the profile showed a decrea Considering the entire profile, the net change was a decrease of 2 feet from 1953 to 1954 althou in the section 1,600 to 2,000 feet from the reference point there was an average net increase 4 feet. The east or left one-third of profile no. 1 has continued to decrease a matter of a few f per year, whereas the right or west two-thirds has shown a pronounced increase starting in 19 During the five year period 1954 through 1959 for the section 900 to 1,600 feet from the referer point, the average increase in surface elevation was 111 feet and for the section between 1,6 and 2,000 the average increase in elevation was 77 feet. The elevation of the approximate w two-thirds of this profile will undoubtedly continue to increase for the next few years. Inasmu as the crest of the wave has apparently passed profile no. 2, the left one-third of profile no will probably not be affected and will continue to decrease in elevation.

The foregoing paragraphs have briefly discussed the changes that have been observed the four profiles. The data provided by these profile measurements indicate that a wave or su has been moving down the glacier. The course of this wave can best be visualized by referer to figure 2 which shows the annual mean elevation for the four profiles. At profile no. 3 th was a continual increase in the mean surface elevation from 1944 to 1951. Thereafter the gene

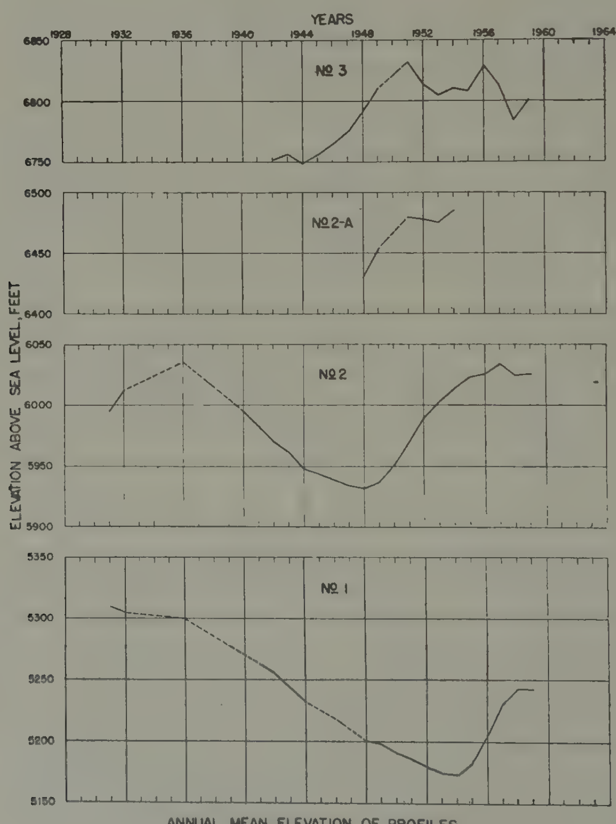
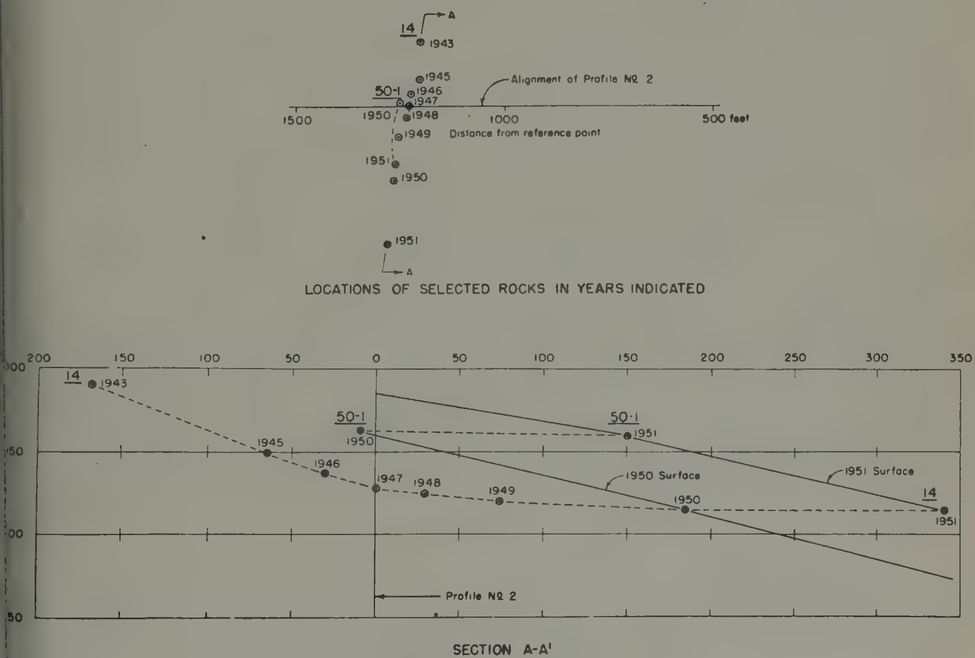


Fig. 2

trend has been a decrease in elevation but with annual fluctuations. At profile no. 2 there was an increase from 1931 to 1936. Sometime between 1936 and 1941 this trend was reversed as the 1941 surface was 53 feet below that in 1936. This decrease continued through 1948. Starting with 1949 the surface elevation increased continually trough 1957 and has been fluctuating both up and down since then. At profile no. 1 ther was a continual decrease in surface elevations from 1931 through 1953. In 1954 a section of the profile near the ringt sideshowed an increase in elevation even though the mean elevation for the entire profile was less than in 1953.

The increase in surface elevation which first became apparent at profile no. 3 in 1945 became evident at profile no. 2 in 1949 or four years later, and at prdfile no. 1 in 1954 or nine years later. The distance from profile no. 3 to no. 2 is 3,500 feet. The wave, therefore, was moving down the glacier at an average rate of almost 900 feet per year in this area during the four year period 1945-1949. The distance from profile no. 2 to no. 1 along the main ice stream is about 2,200 feet. The wave moved forward in this area at a rate of about 440 feet per year.

The rate of movement of this wave is of particular interest when considered along with the known data on the rate of movement of marked boulders on the glacier surface. The rate of movement at profile no. 3 has only been determined for one year. Several markers set near the alignment of profile no. 3 in 1944 were relocated on 1945 and showed a maximum movement of 250 feet for the year interval. During the same year the maximum movement at profile no. 2, 3,500 feet downglacier, was only a matter of 50 to 60 feet or only about one-fifth to one-fourth of the movement at profile no. 3. Considerable information has been obtained on the rate of movement near profile no. 2. During the period 1943-47 the average maximum rate of movement was found to be about 50 to 60 feet per year. Following the increase in surface elevation first observed in 1949, there was an increase in the rate of annual movement of marked boulders



NISQUALLY GLACIER

Fig. 3

starting in 1950. This increased each year through 1958, reaching a value of somewhat o 400 feet from 1957 to 1958. The movement from 1958 to 1959 was only about 300 feet, althou there was no marked change in the surface elevation in this area. As previously pointed out, wave first became apparent at profile no. 2 in 1949. The maximum rate of movement obser in 1949 in the vicinity of profile no. 2 was not appreciably different from that observed previous years, 50 to 60 feet per year. Observations in 1950 showed a maximum of about feet for the preceding year. Observations in 1945 showed that the annual movement near pro no. 3 was four to five times as much as at profile no. 2. If this ratio continued, the movem near profile no. 3 for 1949 to 1950 would have been approximately 700 feet per year.

When the wave first became evident at profile no. 2, the maximum annual movement about 50 to 60 feet per year. The wave, however, had moved from profile no. 3 to no. 2 at a r of almost 900 feet per year. It is evident that the wave moves along the glacier at a much fas rate than the ice mass, at least the surface of the ice mass. The velocity below the surface, in t section of the glacier, is evidently much faster than at the surface.

Figure 3 attempts to visualize and represent the actual movement or change in the glac surface. Two rocks, no. 14 and no. 50-1, as shown in the upper part of figure 3 were essenti on a line normal to the profile alignment but different distances therefrom. The longitudi section, lower part of figure 3, shows the positions and elevations of these two rocks in 1 and 1951. From this it is seen that in each case the elevation of the rocks was within two or th feet of the same value each year. The surface, in general, was 30 to 40 feet higher in 1951 t in 1950. This rise in surface elevation is evidently due to the ice moving faster in the lower p of the glacier than near the surface. The path of travel for rock no. 14 for the years 1943-49 also been indicated. Similar illustrations could be prepared from the available data.

The wave moved from profile no. 2 to no. 1, a distance of 2,200 feet in five years or 440 per year. During the five year period, 1949 to 1954 the maximum annual movement near pro no. 2 increased from 50 to 60 feet to over 300 feet per year. The maximum movement obser from 1953 to 1954 was therefore appreciably less than the average annual forward progres the wave.

The data presented in this paper shows that an increase in the surface elevation of Nisqually Glacier originating above the 7,000 foot elevation moved downglacier as a wave. wave travelled a distance of 5,700 feet in a nine year period or an average of over 600 feet year. The forward advance of this wave was at a much faster rate than the observed rate surface movement. The forward movement of the wave and the increasing elevation of glacier surface was accompanied by a pronounced increase in the annual rate of surface mo ment. Near the 6,000 foot elevation the maximum annual rate of movement increased fr about 50 feet per year for the period 1943 through 1947 to a maximum of over 400 feet dur the year 1957 to 1958. This increase in surface elevation is presumed due to a higher velo of ice movement within the glacier than at the surface. The wave has now reached a point wit one-half mile of the terminus which has shown a continual recession since 1918 when ann observations were started by the Park Service. From historical data, it appears that recess of the terminus has been continuous since about 1885 and even for some time prior thereto. data now available emphasizes the fact that changes observed at the terminus of a glacier not indicative of what is happening to the glacier as a whole.

PARTIE ADMINISTRATIVE

A. — A. I. H. S. — I. A. S. H.

SYMPOSIUM N GROUNDWATER RESOURCES IN ARID ZONES, 1961

This symposium is being arranged by r Association in collaboration with Unesco. all probability it will take place in Athens ring the third quarter of 1961. Exact detail ll be given in the next issue.

National committees of adherent coun- es are requested to seek for authors able offer papers suitable for this symposium, e general programme is that which was ven on page 19 of Bulletin No. 15.

The title, author's name and summary each paper should reach the Secretary the International Association of Scientific ydrology by the 1st. February, 1961, at e latest. The complete text of the paper th its accessories should reach him before e 1st. June 1961. The accessories in ques- n are the figures, drawn on tracing paper cloth and ready for reproduction, also, ould such be necessary, photographs, few in number as possible. The text should t exceed 15 pages of double-spaced types- pt. The figures should be numbered and ch bear the name of the author on the verse.

National committees should kindly amine the scientific value of each paper bmitted before forwarding it to the I.A.S.H. cretariat. They should refuse those papers ich have already been published elsewhere. selection committee of the Groundwater

COLLOQUE SUR LES RESSOURCES EN EAUX SOUTERRAINES DANS LES ZONES ARIDES, 1961

Ce Colloque est organisé par notre Association en collaboration avec l'Unesco. Il aura très vraisemblablement lieu à Athènes au cours du dernier trimestre de 1961. Des précisions seront données dans le prochain bulletin.

Dès à présent, les Comités Nationaux des pays adhérents sont priés de rechercher les auteurs pouvant présenter des communications intéressantes pour ce colloque. Le programme général est celui indiqué dans le bulletin n° 15, page 19.

Les titres, noms des auteurs et un résumé devront nous parvenir au plus tard le 1er février 1961. Les textes complets avec leurs annexes parviendront au Secrétariat de l'A.I.H.S. avant le 1er juin 1961. Les annexes envisagées sont les figures, sur papier transparent, préparées pour la reproduction et le cas échéant (mais en nombre aussi réduit que possible) des photographies. Les textes ne peuvent dépasser 15 pages dactylographiées à double interligne. Les figures seront numérotées et porteront le nom de l'auteur au verso.

Les dirigeants des comités nationaux voudront bien faire examiner la valeur scientifique des communications présentées avant de les faire parvenir au Secrétariat de l'A.I.H. S.. Ils refuseront les rapports publiés antérieurement. Un comité de sélection de la

Commission of I.A.S.H. will decide which papers shall be given priority in being published.

Papers reaching the secretariat after the 1st. June 1961 will not be discussed at the symposium.

Thanks to the generosity of Unesco, grants-in-aid similar to those which have been distributed at other symposia will be available also on this occasion.

Commission des Eaux souterraines de l'I. H.S. choisira les rapports qui seront pub en priorité.

Les communications arrivant au Se tariat après le 1er juin 1961 ne seront pas sentées.

Grâce à la générosité de l'Unesco subventions analogues à celles que nous av déjà réparties pour d'autres Colloques p ront être accordées aux participants.

B. — U. N. E. S. C. O.

1. REPORT OF THE SIXTEENTH SESSION OF THE ADVISORY COMMITTEE ON ARID ZONE RESEARCH

PARIS — MAY 1960

I. INTRODUCTION

The 16th session of the Advisory Committee on Arid Zone Research was held at Unesco House, Paris on 10 and 11 May 1960.

II. REPORTS

The Committee adopted the provisional agenda submitted by the Secretariat.

The Committee heard an oral report on activities since the 15th session and expressed its satisfaction with the work done.

1. RAPPORT SUR LA SEIZIEME SESSION DU COMITE CONSULTATIF DE RECHERCHES SUR LA ZONE ARIDE

PARIS - MAI 1960

I. INTRODUCTION

Le Comité consultatif de recherches la zone aride a tenu sa seizième session Maison de l'Unesco, à Paris, les 10 e mai 1960 .

II. RAPPORTS

Le Comité a adopté l'ordre du jour visoire présenté par le Secrétatiat.

Le Comité a entendu un rapport concernant le travail accompli depuis sa q zième session, et s'en est déclaré satisfait

The Committee then considered the orts concerning projects assisted finan-lly.

. Symposia

The Committee reviewed the arrange-nts made for the General Symposium on id Zone Problems which was to follow the h session. It approved the procedure pro-sed by the Secretariat and nominated pporteurs for the various sessions of the nposium.

The Committee discussed the organi-ion of the Symposium on Climatic Change ich is to be organized jointly with WMO 1961. It noted with satisfaction the arran-nents being made by WMO for their ntribution. It decided that the emphasis of programme it had recommended at its h session should relate to the period of man history. The Committee further re-nmended that the symposium might be d in Rome in the autumn of 1961 imme-tely before or after the meeting of the mmission for Aerology of WMO. It was eed that participants would be selected ntly by Unesco and WMO and that detailed paration and organization of the sym-ium was to be a joint responsibility of the organizations, with the help of special nsultants, if necessary.

The Committee heard a report by Pro-sor L.J. Tison, Secretary-General of the ernational Association of Scientific Hydro-y, on the state of negotiations concerning Symposium on Methods of Evaluating sources of Underground Water with phasis on arid zone problems. In view of limited financial resources available, the .S.H. had felt that a country in the Medi-ranean area would be a suitable location the symposium. The date had not yet been d but some time in the autumn of 1961 med the most appropriate. The Committee ommended that a grant of $6,000 be made he I.A.S.H. to assist it in organizing the nposium, especially to facilitate the par-pation of suitable scientists chosen in sultation with the Secretariat.

Le Comité a examiné les rapports relatifs aux projets qui ont reçu une aide financière de l'Unesco.

III. Colloques

Le Comité a examiné les dispositions prises pour le colloque de portée générale, concernant les problèmes de la zone aride, qui devait faire suite à sa session. Il a approuvé à cet égard les propositions du Secrétariat, et désigné des rapporteurs pour les différentes séances du colloque.

Le Comité a discuté des préparatifs du Colloque sur les changements climatiques, que l'Unesco doit organiser avec l'OMM en 1961. Il a noté avec satisfaction les dispositions déjà prises par l'OMM. Il a décidé que dans l'étude des questions qu'il a recommandées au cours de sa quinzième session, il convien-drait de s'attacher particulièrement aux temps historiques. Il a en outre recommandé que ce colloque se tienne à Rome pendant l'au-tomne de 1961, immédiatement avant la réu-nion de la Commission d'aérologie de l'OMM ou tout de suite après. Il a été décidé que les participants seraient choisis conjointement par l'Unesco et par l'OMM et que le soin de préparer et d'organiser en détail les travaux du colloque incomberait aux deux organi-sations qui agiraient de concert et pourraient au besoin faire appel au concours de consul-tants spéciaux.

Le Comité a entendu un rapport du pro-fesseur L.J. Tison, secrétaire général de l'As-sociation internationale d'hydrologie scien-tifique, sur l'état actuel des pourparlers relatifs à l'organisation d'un «colloque sur les moyens d'évaluer les ressources en eaux souterraines, étudiées notamment du point de vue des pro-blèmes de la zone aride». Vu la modicité des ressources financières disponibles, l'AIHS a estimé qu'il y aurait intérêt à tenir ce colloque dans un pays de la région méditerranéenne. Bien qu'aucune date ne fût encore fixée, il a sembléque l'automne de 1961 serait l'époque la plus favorable. Le Comité a recommandé qu'une subvention de 6.000 dollars soit ac-cordée à l'AIHS pour l'aider à organiser ce colloque et lui permettre d'y faire participer des hommes de science choisis en consultation avec le Secrétariat de l'Unesco.

IV. Training courses

The Committee recommended that of the two regional training and refresher courses to be organized each year in 1961-1962, one course each year should be devoted to hydrology and hydrogeology. A regional course on irrigation improvement might be organized jointly with FAO.

In connexion with the subject of training courses, the Committee heard with interest a proposal by FAO for the joint organization of courses with participants from one country only.

The Committee considered a suggestion that a training course on solar energy utilization and saline water conversion be organized. It felt that such training courses were hardly feasible since they would not be concerned with research methods but with description of existing equipment. The Committee therefore recommended instead that the Science Co-operation Offices in the Major Project region organize information lectures on these two topics.

V. Requests for assistance to research

The Committee considered different requests.

The Committee namely considered the request submitted by Dr. H. Boyko, Israël for assistance towards a research project on irrigation with saline water. It recommended that a sum of $ 2,300 should be granted.

The Committee considered the request submitted by Professor Vassy, Paris, for assistance towards the development of a simple instrument for the recording of absolute humidity and another for recording the ozone content of the air near the soil. It recommended that a grant of $ 1.300 be made.

The Committee still considered the request for assistance towards a symposium on radiation balance and applications of solar energy submitted by the International Union of Geodesy and Geophysics. It recommended that a grant of $ 2,000 be made to assist in holding this symposium in 1961.

IV. Cours de formation

Le Comité a recommandé que l'un deux cours régionaux de formation et de p fectionnement qui doivent être organisés raison d'un par an en 1961-1962 soit consa à l'hydrologie et à l'hydrogéologie. Un co régional sur l'amélioration de l'irrigat pourrait être organisé de concert avec la FA

A propos des cours de formation, Comité a pris connaissance avec intérêt d' proposition de la FAO tendant à l'orga sation en commun de cours destinés aux sortissants d'un seul pays.

Le Comité a examiné une suggestion t dant à l'organisation d'un cours de format sur l'utilisation de l'énergie solaire et le t tement des eaux salines. Il a estimé difficile donner suite à cette suggestion, attendu des cours de ce genre porteraient moins les méthodes de recherche que sur le maté existant. Il a donc recommandé qu'aux et place de ces cours, les postes de coopérat scientifique de la zone d'application du Pr majeur organisent des conférences d'in mation sur les deux questions proposée

V. Assistance a des projets de recherc

Le Comité a examine diverses deman

Le Comité a notamment examiné communication par laquelle le Dr H. Bo (Israël) a sollicité l'aide de l'Unesco pou projet de recherches concernant l'irriga au moyen d'eaux salines. Il a recomma qu'une somme de 2.300 dollars soit affe à l'exécution de ce projet.

Le Comité a aussi examiné la comm cation par laquelle le professeur Vassy (Pa a sollicité l'aide de l'Unesco pour la mis point de deux instruments simples permett l'un de mesurer l'humidité absolue, et l'a de déterminer la teneur de l'air en ozon voisinage du sol.

Le Comité a encore examiné la dema de l'Union géodésique et géophysique in nationale, qui a sollicité l'aide de l'Un pour un colloque sur l'équilibre radiatif e applications de l'énergie solaire. Il a rec mandé qu'une somme de 2.000 dollars affectée en 1961 à l'organisation de ce loque.

Regional projects

The Committee considered some reports. It namely considered the report submitted the Secretariat concerning a proposed ernational handbook on irrigation and inage practices. It noted with satisfaction progress made in the planning of this book l recommended that Unesco make approoate funds available as the project proded.

. Special assistance to institutes

The Committee considered the request equipment submitted by the Desert Rerch Institute, Cairo. It recommended that otal grant of $ 27,000 be made.

The Committee considered the request equipment submitted by the Government India on behalf of the Central Arid Zone search Institute, Jodhpur. It recommended t a grant of $ 45,000 be made for the purse of the equipment requested.

The Committee noted with interest a uest by the Iranian Government for the patch of a short-term mission of arid zone cialists to advise on the development of Arid Zone Research Institute in Iran. ecommended that Unesco meet this request soon as feasible.

The Committee noted that similar rests would be forthcoming from Pakistan l Sudan and recommended that Unesco patch such missions whenever possible.

I. Administrative

The Committee recommended that the retariat consider the possibility of holding next session in conjunction with the nposium on Climatic Change.

VI. Projets regionaux

Le Comité a examiné divers rapports. Il a notamment examiné un rapport du Secrétariat sur le projet de publication d'un manuel international sur les méthodes d'irrigation et de drainage. Il a noté avec satisfaction le progrès des travaux préparatoires et recommandé que l'Unesco fournisse au fur et à mesure les fonds nécessaires.

VII. Aide speciale a des instituts

Le Comité a examiné la demande d'aide présentée, en vue de l'achat de matériel, par l'Institut égyptien du Désert, au Caire. Il a recommandé qu'une somme totale de 27.000 dollars soit accordée a cet Institut.

Le Comité a examiné la demande d'aide présentée par le Gouvernement indien en vue de l'achat de matériel destiné au Central Arid Zone Research Institute de Jodhpur. Il a recommandé qu'une somme de 45.000 dollars soit accordée à cet Institut pour l'achat du matériel en question.

Le Comité a pris acte avec intérêt de la communication du Gouvernement iranien demandant l'envoi en Iran d'une mission à court terme composée d'experts qui guideraient de leurs conseils le développement de l'Institut iranien de recherches sur les terres arides. Il a recommandé que l'Unesco donne suite à cette demande dès qu'elle le pourra.

Le Comité a été avisé que des requêtes analogues seraient prochainement présentées par le Pakistan et le Soudan ; il a recommandé que l'Unesco envoie, autant que possible, les missions demandées.

VIII. Questions administratives

Le Comité a recommandé que le Secrétariat envisage la possibilité de combiner la prochaine session avec le colloque sur les changements climatiques.

ANNEX

LIST OF PARTICIPANTS

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ANNEXE

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national Geographical Union : Professor Dudley Stamp, United Kingdom.
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M. M. Batisse, du Département des sciences exactes et naturelles, secrétaire du Comité

M. W. Moller, du Département des sciences exactes et naturelles.

2. MAJOR PROJECT ON SCIENTIFIC RESEARCH ON ARID LANDS

ADVISORY COMMITTEE ON ARID ZONE RESEARCH

REPORT OF THE SPECIAL REVIEW SESSION

Paris 19-20 May 1960

I. Introduction

The Advisory Committee on Arid Zone Research held a special review session on 19 and 20 May 1960 to evaluate past activities of the arid zone programme and particularly of the Major Project on Scientific Research on Arid Lands to determine the need for future international action in the field of arid zone research, and to make recommendations to the Director-General with regard to the future programme of Unesco in this respect.

A number of former members of the Committee had been invited as observers to this session.

Dr. F. Dixey opened the meeting as Chairman of the 16th session and was elected Chairman of the special session.

The Committee had before it the papers and documents presented at the General Symposium on Arid Zone Problems held in Paris from 11 to 18 May as well as the report summarizing the discussion and the conclusions of the various sessions which are given as Annex to this report.

II. Général évaluation of the programme

The Committee wishes to endorse the general opinion voiced during the Symposium that the arid zone programme of Unesco has been a great success within the context of its objectives.

2. PROJET MAJEUR RELAT AUX RECHERCHES SCIENTIFIQUES SUR LES TERRES ARIDES

COMITE CONSULTATIF DE RECHERCHES SUR LA ZONE ARIDE

RAPPORT DE LA SESSION RÉCAPITULATIVE SPÉCIALE

Paris, 19-20 mai 1960

I. Introduction

Le Comité consultatif de recherche la zone aride a tenu une session récapitul spéciale, les 19 et 20 mai 1960, pour éva les activités passées relevant du progra sur la zone aride et notamment du P majeur relatif aux recherches scientifique les terres arides, afin de déterminer à c besoins devra répondre l'action internatio qu'il y aura lieu d'entreprendre à l'a dans ce domaine, et de faire au Directeur g ral des recommandations quant au futur gramme de l'Unesco à cet égard.

Plusieurs anciens membres du Co avaient été invités à cette session en qu d'observateurs.

M. F. Dixey a été élu président d session spéciale.

Le Comité était saisi des mémoire documents présentés au Colloque généra les problèmes de la zone aride qui ava lieu à Paris du 11 au 18 mai, ainsi que rapports résumant les débats et les conclus des différentes séances (Annexe du pr rapport).

II. Evaluation generale du program

Le Comité tient à confirmer l'opi générale exprimée au cours du colloque l'on considère les buts qui lui étaient assi le programme de l'Unesco relatif à la aride a été une grande réussite.

It is clear that the long-term problems f study and development of arid regions annot be definitely solved by such relatively hort-term efforts as the Major Project and hat therefore any appraisal of past effeciveness and work done must start with reerence to a set of limited objectives. These ave been defined at the 13th session of the dvisory Committee as follows:

To initiate the systematic study of fundaental scientific problems of the arid and emi-arid zones;

To collect and disseminate the scientific nformation arising from studies on arid zone roblems;

To maintain an adequate liaison between he scientists engaged in arid zone research ll over the world with a view to facilitating he co-ordination of their results;

To strengthen institutions devoted to esearch and training in arid zone subjects in he area stretching from North Africa to outh Asia;

To promote in the same area the training f scientists and technicians in arid zone ubjects;

To create greater awareness of the prolems of arid zone research and development n the area through education and public nformation.

The results obtained so far in the light f these objectives are very satisfactory. The Major Project has paved the way to important ew developments in fundamental and applied esearch.

It is also clear that there has been all over he world, and particularly in the region overed by the Major Project, a considerable wakening of public awareness for arid zone roblems.

Finally the activities of Unesco have been eveloped in very close and fruitful co-opeation with the interested international and ational scientific bodies and with the United Nations Organizations concerned.

The Committee wishes to stress the nportance of the Major Project as an excelent example of integrated approach between nany different disciplines and considers that constitutes a most successful endeavour in

Il est évident que les problèmes que posent, à longue échéance, l'étude et la mise en valeur des régions arides ne sauraient être définitivement résolus par un effert d'une durée relativement brève, comme celle du Projet majeur, et que l'évaluation du travail accompli n'a de sens que par rapport à un ensemble d'objectifs bien délimités. Ceux-ci ont été définis à la treizième session du Comité consultatif dans les termes suivants :

Faire étudier systématiquement les problèmes scientifiques de base qui ont trait aux zones arides et semi-arides ;

Réunir et diffuser la documentation scientifique extraite des études consacrées à ces problèmes ;

Entretenir les relations nécessaires entre tous les hommes de science qui poursuivent des travaux sur la zone aride, en vue de favoriser la coordination des résultats obtenus ;

Développer les institutions de recherche et de formation professionnelle pour les matières qui intéressent la zone aride dans la région qui s'étend de l'Afrique du Nord à l'Asie du Sud ;

Encourager dans la même région la formation de spécialistes et de techniciens des mêmes disciplines ;

Faire prendre plus nettement conscience au public, par l'enseignement et par l'information, des problèmes que posent la recherche et la mise en valeur de la zone aride dans la région.

Compte tenu de ces objectifs, les résultats obtenus jusqu'ici sont très satisfaisants. Le Projet majeur a ouvert la voie à des réalisations nouvelles et importantes en matière de recherche fondamentale et appliquée.

Il est évident aussi que l'on constate dans le monde entier, et surtout dans la région à laquelle s'applique le Projet majeur, un éveil marqué de la conscience publique à l'égard des problèmes de la zone aride.

Enfin, l'Unesco a agi en coopération très étroite et très fructueuse avec les organes scientifiques intéressés — internationaux et nationaux — et avec les organisations du groupe des Nations Unies compétentes à cet égard.

Le Comité tient à souligner la haute valeur d'exemple du Projet majeur en tant qu'effort concerté unissant de nombreuses disciplines différentes, et il y voit une très heureuse entreprise de coopération scientifique inter-

international scientific co-operation having wide educational and cultural implications.

III. Considération of future action

It is obvious that Unesco after having launched the international effort that has beenso well described in its report to the Symposium cannot suddenly, at the end of 1962, take no further interest in what happens in the field of scientific research and the training of specialists for the arid and semi-arid regions.

These points were clearly appreciated by the Symposium which was unanimous in pressing for a continuation of the programme of co-ordinated arid zone research on at least the same scale as before, and extended to the whole world and under Unesco's leadership.

Considering the success of the activities carried out and of the methods used in the Major Project, the Committee feels that, from a scientific and efficiency point of view, the best course of action after 1962 would be to maintain within the Unesco framework a substantial programme of activities relating to arid zone research and training extended to all regions of the world affected by aridity, specially Latin America; such a programme would to a large extent be organized along lines similar to those followed so far, although it would take into account the results achieved and experience gained through the Major Project.

At the same time the Committee fully appreciates that the limited resources of Unesco may not permit the allocation for an indefinite period of time and out of the Regular budget of the Organization, of funds and personnel which such a plan would require and which the importance of arid zone problems fully justifies.

The Committee has carefully considered in this connexion the various suggestions made in the working paper prepared by the Secretariat on the future of national and internationa laction for arid zone research.

In broad lines, the Committee suggests that from an administrative point of view the following frame work could be used for a

nationale intéressant, à bien des égards, l'éd
cation et la culture.

III. Examen de l'action a poursuivre

Il est évident qu'après avoir pris l'i
tiative de l'effort international si bien déc
dans son rapport au Colloque, l'Unesco
pourra se désintéresser soudain - à la fin
1962 - de ce qu'il adviendra de la recherc
scientifique et de la formation de spécialis
pour les régions arides et semi-arides.

Les participants au colloque n'ont p
manqué de prendre ces faits en considérati
et ils ont été unanimes à demander que le p
gramme de recherches coordonné sur la zo
aridesoit poursuivi au moins à la même éch
qu'auparavant, qu'il soit étendu au mon
entier et reste sous la direction de l'Unesc

Vu le succès des activités poursuivies
des méthodes employées dans l'applicati
du Projet majeur, le Comité estime que
point de vue de la science et de l'efficacité
meilleure solution, à partir de 1962, serait
maintenir dans le cadre de l'Unesco un i
portant programme de recherches et de f
mation intéressant la zone aride et d'éten
ce programme à toutes les régions du mon
affectées par l'aridité, notamment à l'Am
rique latine.

D'autre part, le Comité comprend t
bien que l'Unesco, dont les ressources so
limitées, risque de ne pas pouvoir prélever
son budget ordinaire, pendant une pério
indéfinie, les fonds et le personnel qu'ex
un plan de ce genre et que justifie pleinem
l'importance des problèmes de la zone ari
Il estime que lorsque le temps sera venu
transformer le programme, cette transf
mation devrait se faire graduellement et ab
tir à une nouvelle phase de coopération sci
tifique internationale entraînant une exp
sion appréciable des activités de recherc

Le Comité a étudié soigneusement, à
égard, les diverses propositions qui figur
dans le document de travail rédigé par le
crétariat sur l'action nationale et inter
tionale future touchant les recherches sur
zone aride.

Le Comité estime que, du point de
administratif, il serait possible de poursui

continued international arid zone research effort:

A. — Specific Unesco activities financed under the Unesco Regular programme

B. — Technical Assistance and Special Fund activities of a national or regional character financed under these program

C. — International research programme financed by national funds outside the Unesco budget.

A. Specific Unesco activities

Recognizing that certain of the tasks involved in this international co-operative effort in arid zone research are particularly suited to Unesco's work and possibilities, the Committee recommends that at least the following activities be maintained within the Unesco programme:

(*a*) The organization of symposia. The distinctive features of the Unesco symposia have been wide geographical participation, high scientific level and a more general approach to problems of arid zone research leading to closer contacts between various scientific disciplines and between fundamental and applied science. Since Unesco, in close co-operation with appropriate international scientific organizations is in a very favourable position to meet all these conditions simultaneously, it is of importance that it should continue to organize symposia in the field of arid zone research.

(*b*) Organization of national and regional training courses.

(*c*) The Fellowship programme. The comments just given apply also to this section.

(*d*) Collection and dissemination of information. The proceedings of symposia should continue to be published. The reviews of research have not yet covered all fields of interest; moreover they will need to be brought up to date as time goes on and revised issues or supplements will become necessary. Unesco is in a central position to ensure the co-operation of the best qualified scientists from all countries in the preparation of information of this kind.

l'effort international de recherches sur la zone aride selon les grandes lignes suivantes:

A. — Activités particulières à l'Unesco financées au titre du programme ordinaire de l'Unesco.

B. — Activités de caractère national ou régional relevant de l'Assistance technique ou du Fonds spécial et financées au titre de ces programmes.

C. — Programme international de recherches financé au moyen de fonds nationaux extérieurs au budget de l'Unesco.

A. Activités particulières à l'Unesco

Constatant que certaines des tâches qu'implique cet effort international collectif de recherches sur la zone aride conviennent particulièrement bien à l'activité et aux ressources de l'Unesco, le Comité recommande qu'à tout le moins les activités suivantes soient maintenues au programme de l'Unesco:

(*a*) Organisation de colloques. Les colloques de l'Unesco se sont distingués par une participation géographique étendue, un niveau scientifique élevé et une façon plus générale d'aborder les problèmes de la recherche sur la zone aride, entraînant des contacts plus étroits entre différentes disciplines scientifiques, comme entre les sciences fondamentales et les sciences appliquées. Puisque l'Unesco, agissant en étroite coopération avec les organisations scientifiques internationales compétentes, est très favorablement placée pour satisfaire à toutes ces conditions, il importe qu'elle continue à organiser des colloques dans le domaine des recherches sur la zone aride.

(*b*) Organisation de cours de formation à l'échelon national et régional.

(*c*) Programme de bourses. Les observations qui précèdent valent aussi pour les bourses.

(*d*) Réunion et diffusion des informations. La publication des actes des colloques doit se poursuivre. Les comptes rendus de recherches n'ont pas encore porté sur tous les domaines d'intérêt ; en outre, il faudra les tenir à jour et publier des numéros révisés ou des suppléments. De par sa position centrale, l'Unesco est à même d'assurer la coopération des savants les plus qualifiés de tous les pays pour établir une documentation de ce genre.

Similarly the newsletter will need to continue as an efficient liaison bulletin between the specialists concerned.

(*e*) Stimulation of national and local co-operating committees.

(*f*) Assistance to small-scale research projects.

The Committee recommends that all these specifically Unesco activities be extended to cover all the arid zones of the world and considers that the geographical limitation of the Major Project should cease with it.

It is also recommended that the Advisory Committee on Arid Zone Research be maintained in order to give guidance in the preparation and execution of the Unecso programme and of the larger research activities mentioned hereafter. It is the view of the Committee that its statutes and constitution need no modification for these purposes.

B. Technical Assistance and Special Fund

The Committee endorses the policy adopted by the Secretariat of closer articulation of the Regular programme with the Technical Assistance programme. Technical Assistance in arid zone projects of various Member States has been very successful and should be continued and expanded.

In certain cases Member States may wish to request support from the United Nations Special Fund for the creation of new institutions or the reinforcement of existing institutions devoted to research and training for arid zone development. Assistance from the Special Fund might also be sought for certain types of experimentation programmes or pilot projects.

C. International research programme

The General Symposium on Arid Zone Problems has shown the need for increased research efforts in many disciplines pertinent to arid zone research. It has resulted in valuable suggestions for research projects which would not only involve several disciplines but would also be of particular intrest to groups of Member States in the arid zone.

De même, il faudra poursuivre la publicatio de «Zone aride», bulletin de liaison très uti pour les spécialistes intéressés.

(*e*) Encouragement des comités de co pération nationaux et locaux.

(*f*) Aide aux petits projets de recherche

Le Comité recommande que toutes c activités particulières à l'Unesco soient éte dues à toutes les zones arides du monde estime que les limites géographiques attaché au Projet majeur devraient disparaître quan ce projet prendra fin.

Il est également recommandé que Comité consultatif de recherches sur la zo aride soit maintenu, afin qu'il puisse guid la préparation et l'exécution du programm de l'Unesco et les activités de recherches pl étendues dont il sera question ci-après. I Comité estime qu'il n'est pas nécessaire po cela de modifier ses statuts ni sa constitutio

B. Assistance technique et Fonds spécial

Le Comité approuve la politique adopt par le Secrétariat en vue d'articuler plus étro tement le Programme ordinaire et le Progran me d'assistance technique. L'assistance tec nique accordée pour des projets relatifs à zone aride mis en oeuvre dans divers Eta membres a donné d'excellents résultats doit être poursuivie et étendue.

Il se peut que dans certains cas des Eta membres souhaitent demander l'appui Fonds spécial des Nations Unies pour cré de nouvelles institutions ou pour renforc celles qui se consacrent déjà à la recherche à la formation pour la mise en valeur de zone aride. L'aide du Fonds spécial peut aus être demandée pour certains types de pr grammes d'expérimentation ou de projet pilotes.

C. Programme international de recherch

Le Colloque général sur les problèmes la zone aride a fait ressortir la nécessité d'a croître les efforts de recherches dans beauco de disciplines aptes à participer à la recherc sur la zone aride. D'utiles suggestions ont faites à cette occasion en vue d'entreprend des projets de recherches intéressant à la fo plusieurs disciplines et plusieurs Etats me

The Committee has not had time to consider with due attention all these suggestions, most of which are given in Annex II. It has nevertheless expressed certain preferences and suggested the following research projects or programmes as particularly suited to international action:

(*a*) A scientific study of the artesian basins of Northern Africa:

(*b*) A series of integrated surveys: an integrated survey may be defined as the co-ordinated collection and interpretation of data inter alia on geomorphology, geology, pedology, ecology, microclimate, plant associations and water supplies of a sample area and it should also, where required, include matters related to human occupancy:

(*c*) Co-ordinated study of plant response to arid environmental factors: the importance of undertaking a co-ordinated programme of co-operative research concerning some urgent problems in plant physiology and experimental ecology is recognized.

Other subjects of importance which could suitably be developed as large-scale international research programmes are certain aspects of the following major fields:

(*d*) Arid zone soil biology,

(*e*) insect pests and plant diseases

(*f*) human diseases linked with irrigation systems,

(*g*) human and animal physiology under arid zone conditions.

The Committee is of the opinion that well planned and co-ordinated research projects mentioned above would lead to considerable progress, and it is confident that their significance would call for the raising of the necessary contributions from Member States or from research foundations and similar sources.

It is considered that the Advisory Committee, as now constituted, with observers from the United Nations Organizations and international scientific organizations, would constitute adequate machinery for the action and co-ordination of such a research plan, the administration of which could be handled by the Secretariat of Unesco. For the detailed planning and supervision of

bres faisant partie de la zone aride. Le Comité n'a pas eu le temps d'examiner avec toute l'attention désirable ces nombreuses suggestions. Il a néanmoins exprimé certaines préférences et considéré que les projets ou programmes de recherches mentionnés ci-après se prêtaient particulièrement bien à une action internationale:

(*a*) L'étude scientifique des bassins artésiens de l'Afrique du Nord:

(*b*) Une série d'études intégrées: On peut définir l'étude intégrée comme le rassemblement et l'interprétation systématiques pour une zone choisie comme échantillon - de données relatives à la géomorphologie, à la géologie, à la pédologie, à l'écologie, au microclimat, aux associations végétales et aux ressources en eau, données auxquelles viendraient s'ajouter, le cas échéant, des renseignements sur l'élément humain.

(*c*) Des études coordonnées sur les réactions des végétaux en milieu aride: on a reconnu l'importance d'un programme coordonné de recherches communes sur quelques problèmes urgents en matière de physiologie végétale et d'écologie expérimentale.

D'autres grands programmes internationaux de recherches pourraient porter utilement sur certains aspects des domaines suivants:

(*d*) biologie des sols de la zone aride;

(*e*) insectes nuisibles et maladies des plantes;

(*f*) maladies de l'homme liées aux systèmes d'irrigation;

(*g*) physiologie humaine et animale dans la zone aride.

Le Comité estime que des projets de recherches bien conçus et coordonnés sur les sujets mentionnés ci-dessus pourraient amener des progrès considérables et il est convaincu qu'en raison de leur importance il serait légitime de faire appel à la contribution des Etats membres ou des fondations de recherches et autres organismes analogues.

Le Comité consultatif, dans sa forme actuelle, avec des observateurs des organisations appartenant au groupe des Nations Unies et des organisations scientifiques internationales, paraît constituer l'organe approprié pour l'application et la coordination d'un plan de recherches de ce genre, dont l'administration pourrait être confiée au Secré-

specific projects, appropriate sub-committees or expert groups would naturally be convened as necessary.

The provision of funds might take two forms:

(*a*) An international arid zone research fund to which contributions would be made by Member States - and possibly by rescarch foundations and similar bodies - for an agreed general research programme including a number of projects. Within the frame work of this programme, the resources would then be used as the Advisory Committee recomends.

(*b*) Separate funds for individual research projects provided from specific contributions made by Member States and possibly research foundations and sumilar bodies.

The Advisory Committee considers that the first possibility would be simpler and more efficient than the second and that the experience acquired and the success achieved in the operation of the Major Project would justify the confidence implied in its adoption. The second method could nevertheless be adopted for well defined large-scale projects.

ANNEX

SUMMARY REPORTS ON SESSIONS OF THE GENERAL SYMPOSIUM ON ARID ZONE PROBLEMS

PARIS 11-18 MAY 1960

For each of the main subjects dealt with in the symposium a special report had been prepared and distributed in advance to participants. Chairmen were appointed to preside over the presentation and discussion of these reports. In addition, members of the Advisory Committee were designated as rapporteurs and requested to summarize the main points arising from each discussion. The summaries prepared by the rapporteurs are given below and it is felt that the suggestions made therein

tariat de l'Unesco. Pour la planificati détaillée et le contrôle des divers projets, d sous-comités ou des groupes d'experts sp cialisés seraient naturellement constutiés sel les besoins.

Le financement pourrait se faire so deux formes différentes:

(*a*) Un fonds international pour les cherches sur la zone aride, alimenté par Etats membres - et éventuellement par d fondations de recherches et organes similai - servant à l'application d'un programme néral de recherches accepté par tous et co prenant un certain nombre de projets. Da le cadre de ce programme les crédits seraie alors utilisés suivant les recommandations Comité consultatif.

(*b*) Des fonds distincts pour les différe projets de recherches seraient alimentés des contributions versées spécialement les Etats membres et peut-être par des fo dations de recherches et organes similair

Le Comité consultatif considère que première de ces deux solutions serait la p simple et la plus efficace, et l'expérience quise et les succès obtenus lors de la mise oeuvre du Projet majeur justifieraient la co fiance qu'impliquerait son adoption. La conde méthode pourrait néanmoins ê suivie pour de grands projets bien défin

ANNEXE

RAPPORTS SUCCINCTS RELATIFS AUX SEANCES DU COLLOQUE GENERAL SUR LES PROBLEMES DE LA ZONE ARIDE

PARIS, 11-18 MAI 1960

Sur chacun des principaux sujets e minés lors du colloque, un rapport spé avait été rédigé et distribué à l'avance participants. Des présidents ont été appe à diriger la présentation et la discussion ces rapports. Enfin, des membres du Com consultatif ont été désignés comme rapp teurs et chargés de résumer les principa points qui se sont dégagés des débats. trouvera ci-après les comptes rendus éta par ces rapporteurs ; les suggestions qu

ill be of great value in the preparation of ıture activities by all those concerned.

figurent devraient être très précieuses pour tous ceux qui auront à préparer les activités futures.

ART 1 - STATE OF SCIENTIFIC KNOWLEDGE

Surface water (including sedimentation), report by Dr. W.B. LANGBEIN Chairman: Professor L.J. TISON, Rapporteur: Dr. LUNA B. LEOPOLD

1. Much information, data, measuement and experience in hydrology has been ıd is being accumulated in various countries. ecause no one country has a complete range f hydrologic conditions, hydrologists in ıch country vitally need to have access to ie data and experience of others. At present, iis is not possible. It is recommended that ie Advisory Committee point out this need WMO and offer whatever assistance can rendered by Unesco. It is urged that a al effort be initiated to assemble carefully iosen examples of such data in some uniform ianner, and disseminate these summaries to arious countries. An example might be data precipitation, flood peak, run-off volume, om selected storms on drainage areas of ss than 200 square miles, and for which data e available on soils, slopes, vegetation, ologic formation, drainage area, drainage etwork, and channel characteristics.

2. Research is needed on ways of manang a variable resource. At present a conflict ists. Small reservoirs as well as large ave been suggested as a way to utilize cal flash flood water. The disadvantages e wellknown: more capacity is needed, dimentation and evaporation rates are gh. On the other hand, large-scale integrated evelopment plans for water use tend to enurage only systems of use which require dependable supply. Thus, water is lost to e during extremely wet periods, and in dry riods the supply is insufficient to meet all emands.

A new area of research is needed dealing multaneously with both the hydrologic and cioeconomic aspects. It is recommended iat Unesco sponsor a competent hydro-

PREMIERE PARTIE - ETAT DES CONNAISSANCES SCIENTIFIQUES

I. Hydrologie des eaux superficielles (y compris la sédimentation), rapport de M. W. B. LANGBEIN. Président: M. L. J. TISON ; rapporteur; M. LUNA B. LEOPOLD.

1. Beaucoup de renseignements, de données, de mesures et d'expériences en matière d'hydrologie ont été et sont encore accumulés dans différentes pays. Aucun pays ne présentant toute la variété des conditions hydrologiques, les hydrologues ont absolument besoin d'avoir accès aux données et à l'expérience de leurs confrères étrangers. A l'heure actuelle, ce n'est pas possible. Il est recommandé que le Comité consultatif signale à l'OMM cette nécessité et offre toute l'assistance que l'Unesco est en mesure d'apporter. Il faudrait prendre l'initiative d'un effort concret pour rassembler des exemples de renseignements soigneusement choisis en assurant d'une manière ou d'une autre leur uniformité, puis diffuser ces résumés dans divers pays. Il s'agirait, par exemple, de données sur la précipitation, l'écoulement maximal, le volume du ruissellement dans le cas de fortes chutes de pluie, déterminés sur des zones de draînage de moins de 520 kilomètres carrés, et pour lesquels on dispose de renseignements concernant les sols, les pentes, la végétation, les formations géologiques, la zone de draînage, le réseau de draînage et les caractéristiques d'écoulement.

2. Il y aura lieu de faire des recherches sur les façons d'aménager une ressource variable. Actuellement, il y a conflit. On a préconisé l'installation de petits réservoirs, en plus des grands, pour utiliser les eaux superficielles en soudaine et brève abondance. Les inconvénients en sont bien connus: la capacité doit être plus grande, les taux de sédimentation et d'évaporation sont élevés. Cependant, lorsqu'ils sont à une grande échelle, les plans de développement relatifs à l'utilisation des eaux ont tendance à n'encourager que des systèmes d'exploitation qui exigent des ressources

economist to evolve a model plan involving the essential hydrologic, land-use, and economic factors, pointing the way to sound utilization of a varying resource.

II. Geology, geomorphology and ground water hydrology, report by Dr. F. Dixey Chairman: Professor A. Desio, Rapporteur: Proffesseur E.S. Hills

The discussion underlined the importance of the continuation of research along established lines and the need for prosecuting further fundamental studies as outlined in the paper by Dr. Dixey, and laid special emphasis on the folowing points referred to in the paper:

(*i*) The need for the study of the water balance, more particularly in the exploitation of limited resources of underground water in defined basins:

(*ii*) The importance of geomorphological mapping in relation to the understanding of soils, plant ecology and water exploitation:

(*iii*) The need to make full use of geophysical methods:

(iv) The need to ensure joint action by the scientists of different countries concerned in the study of large underground water basins which extend beyond the limits of any one country, with a view to mutual agreement among the authorities concerned, as to the controls required in the utilization of water.

In particular, in this regard, the symposium recognized the importance of an international study of the artesian basins of Northern Africa, with special reference to the Intercalaire Continental, so as to ensure their optimum development for economic and social progress and mutual agreement on such controls as may be necessary.

assurées. Ainsi l'eau se perd pendant les riodes extrêmement humide sa lorsque p dant les périodes sèches le ressources sont suffisantes pour répondre à tout les beso

Il convient d'étudier simultanément aspects hydrologiques et les aspects soc économiques du problème. Il est recomma que l'Unesco donne à un hydro-économ compétent la possibilité d'élaborer un pl pilote qui tienne compte des facteurs hyd logiques et économiques essentiels - y comp l'utilisation des terres - et qui ouvre la v à l'utilisation rationnelle d'une ressou variable.

II. Géologie, géomorphologie et hydrolo des eaux souterraines, rapport M.F. Dixey. Président : M.A. Des Rapporteur : M.E.S. Hills.

Les débats ont fait ressortir la néces de continuer les recherches selon les princi établis, et de poursuivre les études fondam tales indiquées dans le mémoire de M. Dix On a beaucoup insisté sur les points suivan mentionnés dans le mémoire :

(i) nécessité d'étudier le bilan hydriq notamment en vue de l'exploitation des r sources limitées en eaux souterraines d des bassins déterminés ;

(ii) nécessité primordiale de la ca graphie géomorphologique pour la conna sance des sols, de l'écologie végétale et l'exploitation des eaux ;

(iii) nécessité d'appliquer pleinement méthodes de géophysique ;

(iv) nécessité d'assurer l'action conjoi des savants de différents pays s'occupant l'étude des grands bassins d'eaux souterrai que s'étendent au-delà des limites d'un pays, en vue d'arriver à des accords entre autorités intéressées pour assurer les contrô nécessaires sur l'utilisation de ces eaux.

A cet égard, les participants au collo ont estimé notamment qu'il serait très u d'entreprendre, à l'échelon internatio l'étude des bassins artésiens de l'Afrique Nord, particulièrement l'intercalaire c tinental, pour en assurer la mise en val dans les conditions les plus favorables au p grès économique et social, et en vue d'abo aux accords qui seraient nécessaires à l'ex cice de ces contrôles.

III. Climatology and hydrometeorology with special regard to the arid lands, report by Dr. C.C. Wallen.
Chairman: Dr. S.N. Naqvi, Rapporteur: Dr. Luna B. Leopold.

1. The network of observation stations for climatological purposes is dense where water is plentiful and least dense where water is short. Moreover, observation is more difficult where precipitation is local and infrequent. Not only are more observation necessary but the organization, publication and dissemination should be better co-ordinated. It is recommended that the Advisory Committee convey to WMO the necessity for still further attention to such work. It may be appropriate to make an overall survey of the present situation in so far as the arid zone is concerned, and then devise a joint effort for the establishment of special stations and for the extension of the present network.

2. For knowledge of long-term variations in climatic factors, it is necessary that there be a system of bench-mark stations which are both permanent in time and uninfluenced by urbanization or other man-made influences. Despite the urging by WMO, such permanent stations do not yet exist in all countries. At least a few precipitation and temperature stations, perhaps chosen from suitable stations now in operation might be so designated. The records from such stations should be published in a uniform manner. It is recommended that countries interested in arid zone problems implement the recommendations already made by WMO for the establishment of bench-mark stations, and for Unesco to assist in co-ordination leading to publication of those records.

3. As in other fields, climatology relies greatly on publication of records. The publication problem needs additional stress. Many of the research projects now sponsored by Unesco may not necessarily lead to the publication of basic data. Standardization of definitions and of schemes of publication is an international problem in which Unesco can play an important part.

III. Climatologie et hydrométéorologie spécialement appliquées aux terres arides, rapport de M. C. S. Wallen
Président : M. S. N. Naqvi ; Rapporteur : M. Luna B. Leopold

1. Le réseau des stations d'observation de climatologie est dense là où l'eau est abondante, et plus clairsemé dans les régions où elle est rare. En outre, l'observation est plus malaisée lorsque les précipitations sont localisées et peu fréquentes. Non seulement les observations doivent être plus nombreuses, mais l'organisation, la publication et la diffusion des données doivent être mieux coordonnées. Il est recommandé que le Comité consultatif signale à l'OMM la nécessité d'attacher plus d'attention encore à ce genre de travail. Il pourrait être opportun de faire une enquête générale sur la situation présente en ce qui concerne la zone aride, puis d'organiser un effort commun pour créer des stations spéciales et étendre le réseau actuel.

2. Pour connaître les variations à long terme des facteurs climatiques, il est indispensable de disposer d'un ensemble de stations de base qui soient permanentes et qui échappent à l'influence de l'urbanisation et autres perturbations d'origine humaine. Malgré les recommandations instantes de l'OMM, ces stations permanentes n'existent pas encore dans tous les pays. Il devrait être possible de désigner au moins quelques stations pour l'étude des précipitations et de la température, en les choisissant éventuellement parmi les stations qui fonctionnent déjà. Les observations de ces stations seraient publiées de manière uniforme. Il est recommandé que les pays qui s'intéressent aux problèmes de la zone aride s'appliquent les recommandations déja faites par l'OMM en vue de la création de ces stations de référence, et que l'Unesco aide à coordonner la publication de leurs observations.

3. Comme les autres disciplines, la climatologie dépend beaucoup de la publication des observations. Ce problème de la publication doit être souligné à nouveau. Il est à craindre que de nombreux projets de recherches actuellement patronnés par l'Unesco ne conduisent pas nécessairement à la publication de données de base. La normalisation des définitions et des modes de publications est

IV. Report on microclimatology, report by Professors W.R. VAN WIJK and J. de WILDE.
Chairman: Dr. H. WALTER, Rapporteur: Dr. L.A. RAMDAS.

1. Arid zones, being at present very scantily covered by vegetation, tend to develop the extreme type of microclimate of the «open» space, with conspicuous diurnal variation and gradients of temperature which are both maximum at the «active» ground surface and decrease in intensity rapidly away from the surface. Upward diffusion of water vapour by evaporation by day is compensated during night time by opposite diffusion and invisible or visible (dw) condensation on the surface during the long dry spells.

2. When, as a result of reclamation, the arid zones begin to develop a mantle of vegetation, the microclimate will undergo a considerable and significant transformation whith milder temperatures with less diurnal variation, higher humidity and decreased wind in the air layers near the ground; this change in the microclimate wil be proportional to the plant density and height and most accentuated when the plant community forms a canopy at the top which will then behave as the «active» surface.

When this change sets in, the climate near the ground will no doubt become more congenial to all living beings, but there is at the same time the grave risk of plant pests and diseases also developing and assuming sometimes epidemic proportions.

So it is essential that microclimatologists work in very close co-operation with biologists engaged in the study of the incidence, intensity and control of such adverse pests and diseases.

3. The development of methods of conservation and most economic use of the scanty water resources in the arid zone for maximizing food production and techniques for assessing the factors controlling the water balance at the ground assume a very special importance. There is urgent need, particularly,

un problème d'ordre international à l'égarc duquel l'Unesco peut jouer un rôle important

IV. Rapport sur la microclimatologie. Rapport de MM. W.R. VAN WIJK et J. de WILDE
Président : M. H. WALTER ; Rapporteur : M. L.A. RAMDAS

1. Les régions arides n'étant actuellement couvertes que d'une végétation trè rare, on y trouve généralement le type extrêm du microclimat des espaces ouverts avec d très fortes variations diurnes et des gradient de température qui sont maximums à la sur face «active» du sol et diminuent rapidemen en intensité à partir de la surface. La diffusio ascendante de la vapeur d'eau par évaporatio pendant le jour est compensée, pendant l nuit, par une diffusion en sens opposé et un condensation invisible ou visible à la surface pendant les longues périodes de sécheresse

2. Quand, par suite de la remise en éta des terres, les zones arides commencent à s couvrir d'un manteau de végétation, le mi croclimat subit une transformation consi dérable et significative, caractérisée par de températures plus douces, avec des variation diurnes moins prononcées, une plus grand humidité, et des vents moins forts dans le couches d'air proches du sol ; cette évolutio du microclimat est d'autant plus marquée qu la couverture est plus dense et plus haute, e elle atteint son maximum lorsque le somme de la population végétale forme comme u tapis, qui se comporte alors comme une sur face «active».

Lorsque ce changement se produira, l climat près du sol deviendra sans doute plu propice aux êtres vivants, mais il est à craindr que les maladies et les parasites ne se dévelop pent en même temps, en prenant parfois le proportions d'une épidémie.

Il est donc indispensable que les micro climatologistes travaillent en très étroite co laboration avec les biologistes qui étudier l'incidence et l'intensité de ce danger, et le moyens de lutter contre les parasites et l maladies.

3. Il importe particulièrement de mett au point des méthodes pour conserver utiliser au mieux les rares ressources en ea

for improving the precision in the estimation of «natural» evaporation and evapotranspiration.

Both the theoretical and the practical or experimental approaches for securing such valid estimates, therefore, deserve active encouragement from Unesco, WMO and FAO.

4. There are several hierarchies of «microclimate», ranging from the «micro-micro» variations of the smallest insect environment to the variations within larger spaces such as occur within plant or forest communities, buildings, cities, or around hillocks, hills, etc. The actual scope of the term «micro» should, therefore, be clear in every particular context.

5. Care is necessary to ensure that in microclimatic researches the experimental techniques are adequate for the particular purposes in view, it being equally essential to avoid over-simplification of techniques on the one hand as much as over-instrumentation on the other.

V. Arid zone soils - A study of their formation, characteristics, utilization and conservation, report by Dr. GEORGES AUBERT.
Chairman: Dr. H. GREENE, Rapporteur: Dr. ABDUL HAFIZ.

VI. Salt-affected soils and plants, report by Dr. L. BERNSTEIN.
Chairman: Professor A.K. KHUDAIRI, Rapporteur: Dr. ABDUL HAFIZ.

VII. Plant physiology and arid zone research, report by Professor M. EVENARI.
Chairman: Mr. N. EL GHORFI, Rapporteur: Professor P. CHOUARD.

VIII. Plant ecology, reports by Professors G. LEMEE and L. EMBERGER.
Chairman: Dr. B.T. DICKSON, Rapporteur: Professor P. CHOUARD.

de la zone aride, afin de porter au maximum la production des denrées alimentaires, ainsi que des techniques permettant d'évaluer les éléments qui déterminent le bilan hydrique au sol. Il est particulièrement urgent de pouvoir évaluer de façon plus précise l'évaporation et l'évapo-transpiration «naturelles».

Les méthodes tant théoriques que pratiques ou expérimentales visant à obtenir des évaluations suffisamment précises méritent donc d'être activement encouragées par l'Unesco, l'OMM et la FAO.

4. Il existe plusieurs degrés de «microclimats», depuis les variations extrêmement limitées intéressant un petit peuplement d'insectes jusqu'aux variations que l'on observe dans les espaces plus étendus, comme celles qui se produisent dans une formation végétale ou forestière, dans les bâtiments et les villes, ou autour des collines, des montagnes etc. La portée du terme «microclimat» doit donc être précisée dans chaque cas.

5. Il faut s'assurer que, dans les recherches microclimatiques, les techniques d'expérimentation sont adaptées aux buts à atteindre ; oo évitera aussi bien la simplification excessive des techniques que le suréquipeAent.

V. Pédologie de la zone aride. Etude de la formation des sols, de leurs caractéristiques, de leur utilisation et de leur conservation. Rapport de M. Georges AUBERT
Président : M. H. GREENE ; Rapporteur : M. ABDUL HAFIZ

VI. Problèmes phytologiques et pédologiques relatifs à la salinité, rapport de M. BERNSTEIN.
Président : M. A.K. KHUDAIRI ; Rapporteur : M. ABDUL HAFIZ

VII. Physiologie végétale et recherches sur la zone aride, rapport de M. EVENARI
Président : M. N. EL GHORFI ; Rapporteur : M. P. CHOUARD

VIII. Ecologie végétale, rapports de MM. G. LEMEE et L. EMBERGER
Président : M. B.T. DICKSON ; Rapporteur : M. P. CHOUARD

IV. Applications of human and animal physiology and ecology to arid zone problems, report by Dr. D.H.K. Lee. Chairman: Professor J. Magnes, Rapporteur: Professor M. M. Ramadan.

X. Development of arid lands and its ecological effects on their insect fauna, report by Dr. B.P. Uvarov. Chairman: Professor J. Magnes, Rapporteur: Professor M.M. Ramadan.

XI. Local energy sources, reports by Mr. E.W. Golding and Dr. H. Tabor. Chairman: Dr. S.R. Meehra, Rapporteur: Dr. L.A. Ramdas.

Discussions on wind and solar energy brought out again very clearly an important point (stressed at the New Delhi Symposium), viz., that the proper policy is to treat wind solar and fuel energies as supplementary to each other and an integrated approach on this line is essential to solve the problem of power availability in rural areas.

A. Energy from wind and local fuels

1. Some parts of the arid zones have wind regimes that may be utilized with advantage. Unesco should disseminate the results of wind power research in some of the advanced countries amongst the Desert Research Institutes and National Committees in the countries of the arid zones and thus encourage the use of wind energy where advisable.

2. Organizations concerned in the arid zones should, if they have not already done so, carry out wind surveys so as to map the areas where such energy may be available to a sufficient extent and to point out favourable locations therein (e.g. hill-tops, gaps in hill ranges, etc., where the wind may be much stronger than in adjoining areas).

IX. Applications de la physiologie et d l'écologie humaines et animales au problèmes de la zone aride, rapport d M. D.H.K. Lee
Président : M. J. Magnes ; Rappor teur : M. M.M. Ramadan

X. La mise en valeur des terres arides et se effets écologiques sur les insectes, rappor de M. B.P. Uvarov
Précident : M. J. Magnes ; Rappor teur : M. M.M. Ramadan

XI. Sources locales d'énergie, rapports d MM. E.W. Golding et H. Tabor
Président : M. S.R. Mehra ; Rappor teur : M. L.A. Ramdas

Les débats sur l'énergie éolienne et so laire ont fait une fois de plus ressortir trè clairement un point important (souligné a Colloque de New Delhi) à savoir qu'il fau considérer comme complémentaires les éner gies éolienne et solaire, et celle qui émane d'u combustible ; et qu'il est indispensable d coordonner les efforts pour résoudre le pro blème de l'énergie dans les régions rurale

A. Energie éolienne et combustibles locau

1. Dans certaines parties des zones aride le régime des vents peut être utilisé avec profi L'Unesco devrait diffuser les résultats de recherches entreprises dans quelques pay avancés sur l'énergie éolienne en les commun quant aux Instituts de recherches sur le dése et aux Comités nationaux des pays de la zon aride ; l'emploi de l'énergie éolienne sera ainsi encouragé là où il peut être utile.

2. Les organisations qui s'intéressent au régions arides devraient, si elles ne l'ont pa encore fait, étudier les régimes des vents e vue d'établir pour ces régions des cartes in diquant les zones où cette énergie pourra atteindre un degré suffisant et présisant que seraient les points les plus favorables (somme des collines, cols dans les chaînes de mon tagnes, etc. où le vent peut être beaucoup plu fort qu'ailleurs).

3. Unesco may encourage further ex-
erimental projects on utilization until the tage is reached when manufacturers can ndertake the manufacture of those types f installations that promise to be most useful.

. Solar energy

1. To encourage further break-throughs a solar energy utilization, Unesco should ive every possible encouragement to theo-etical and experimental research that may ccelerate further progress, as for example, a the direct conversion of solar energy into lectrical power.

2. Besides water heating and solar ooking, refrigeration and air-conditioning y using solar energy hold much promise or the future and research on this problem of special significance to hot and arid zones.

3. The stage has arrived where market esearch by economist and social scientists o determine what is needed, whether and here acceptable, optimum sizes of equip-ient and likely volume of business, is needed n a world-wide basis. Research on these nes should be encouraged.

4. The Unesco-WMO programme for ollection and processing of radiation data n a world-wide basis should continue.

II. Saline water conversion, report by Dr. E.D. Howe.
Chairman: Dr. S.R. Meehra, Rapporteur: Dr. L.A. Ramdas.

1. The use of solar water distillers for roviding drinking water in very arid zones as already been stressed. Research on method f increasing the efficiency of such apparatus hould be encouraged.

3. L'Unesco pourrait encourager de nouveaux projets expérimentaux sur l'utilisation de l'énergie éolienne, afin d'en arriver au stade où il sera possible d'entreprendre la fabrication industrielle des types d'installations paraissant les mieux conçus.

B. Energie solaire

1. Pour contribuer à ouvrir de nouvelles voies dans le domaine de l'utilisation de l'énergie solaire, l'Unesco devrait encourager le plus possible la recherche théorique et expérimentale pouvant amener de nouveaux progrès comme, par exemple, la conversion directe de l'énergie solaire en énergie electrique.

2. Outre son utilisation pour chauffer l'eau et cuire les aliments, l'énergie solaire paraît offrir d'intéressantes possibilités pour la réfrigération et la climatisation, et les recherches sur ce problème prennent une importance particulière dans les régions chaudes et arides.

3. On a atteint le stade où des études de marché doivent être entreprises à l'échelle mondiale : des économistes et des sociologues devront déterminer quels sont les besoins, à quelles conditions et en quels lieux l'énergie solaire paraît être utilisable, quelles sont les dimensions les meilleures à adopter pour le matériel, quel sera le volume probable des transactions, etc. Il convient d'encourager la recherche dans ces différentes directions.

4. Le programme Unesco-OMM visant à réunir et à exploiter les données relatives aux radiations doit être poursuivi sur une base mondiale.

XII. Déminéralisation des eaux salines, rapport de M. E.D. Howe
Président : M. S.R. Mehra ; Rapporteur : M. L.A. Ramdas

1. L'emploi des distillateurs solaires pour la fourniture d'eau potable dans les zones très arides a toujours été préconisé. Des recherches sur les méthodes visant à accroître l'efficacité de ces appareils devraient être encouragées.

2. Electrodialysis has been demonstrated as a successful technique for providing drinkingwater for men and animals on an economic basis at the subsistance level. Further research on membranes and cell desings to further increase the efficiency of desalinization by this process deserves urgent encouragement.

3. Research on other techniques such as: (a) freezing separation; (b) reversed osmosis; (c) solvent extraction and (d) other possible methods of desalinization should also be encouraged, as water for drinking and irrigation purposes is the most vital problem for the arid zones of the earth.

4. Unesco should also arrange for the demonstration of the various desalinization techniques so far developed in the countries constituting the arid zones. A contest could be organized for the design of a small-scale demineralization equipment easily transportable which could be used for drinking needs of men and animals.

Part 2 — Action undertaken

Reports of activities by Unesco, the UN Agencies, Member States and International Scientific Organizations.
Chairman: Professor Gilbert F. White, Rapporteur Dr. F. Dixey.

National reports on arid zone activities prepared at the request of the Director-General of Unesco were received and distributed for information to the symposium from the following Member States in the Major Project area: India, Iran, Iraq, Morocco, Pakistan, Sudan and the United Arab Republic. Arid zone activities reports were distributed and presented from the following international scientific organizations: International Geographical Union, International Commission on Irrigation and Drainage, International Union for Geodesy and Geophysics, International Union for Conservation of Nature and Natural Re-

2. L'électrodialyse est une techniqu qui a donné de bons résultats pour la fou niture d'eau potable aux humains et aux an maux dans des conditions rentables au nivea du minimum physiologique. Il faudrait e courager d'urgence la recherche sur les mem branes et les cellules pour augmenter l'effic cité de la déminéralisation par ce procéd

3. Les recherches sur d'autres techniqu telles que : (a) la séparation par congélatio (b) par pression osmotique inversée, (c) l'e traction au moyen de solvants, et (d) tou autre méthode possible de déminéralisatio doivent aussi être encouragées, car le pr blème de l'eau, tant pour la consommatio que pour l'irrigation, est le plus vital qui pose dans les régions arides.

4. L'Unesco devrait aussi faire procéde dans les pays qui appartiennent aux zon arides, à des démonstrations portant sur l différentes techniques de déminéralisati connues à ce jour. On pourrait organiser u concours pour la réalisation d'un appareil déminéralisation de petite dimension, ais ment transportable et pouvant être utili pour les besoins en eau potable de l'homn et des animaux.

Deuxieme partie - action entreprise

Rapports sur les activités entreprises p l'Unesco, les autres organisations du grou des Nations Unies, les Etats membres et l organisations scientifiques international Président : M. Gilbert F. White ; Rappo teur : M. F. Dixey

Des rapports nationaux sur les activit relatives à la zone aride, rédigés à la deman du Directeur général de l'Unesco, ont é adressés par plusieurs Etats membres situ dans la zone d'application du Projet m jeur : Inde, Irak, Iran, Maroc, Pakista République arabe unie et Soudan. Ces ra ports ont été distribués pour l'informati des participants au colloque. Les organis tions scientifiques internationales ci-après o également fait parvenir et distribuer d rapports sur leurs activités dans la zone arid Union géographique internationale, Co mission internationale d'irrigation et drainage, Union géodésique et géophysiq

ources and Commission for Technical Co-operation in Africa South of the Sahara. Similar reports prepared by the interested United Nations Agencies, namely, the Water Resources Development Centre of the United Nations, FAO, WHO and WMO were also distributed and presented.

The comprehensive report prepared by Unesco covering the activities undertaken since the beginning of the arid zone programme gave rise to a good discussion in which 18 speakers took part, expressing views from most of the Major Project areas and from several Latin American countries.

The speakers paid high tribute to the activities and achievements of the arid zone programme, and particularly to the work of Mr. Batisse and his staff, and the view that the programme should be continued in some suitable form and extended to other areas was unanimously expressed.

The view was strongly urged that in the short time and with the limited funds available, substantial results had been achieved.

Many suggestions were made for consideration in the future among which the following should be mentioned:

1. More mapping, particularly geomorphological, should be undertaken.

2. Greatly increased provision should be made for the collection of fundamental and reliable data, (especially of precipitation) so that rsearch efforts can be based on solid grounds.

3. Studies of evapotranspiration, reduction of evaporation, water balance, and continental erosion should be emphasized.

4. Ecological work should be extended, especially in areas not yet greatly affected by man, as on the southern fringes of the Sahara, and the ecological effects of land use in relation to aridity.

5. Further help and encouragement should be given to National Committees.

internationale, Union internationale pour la conservation de la nature et de ses ressourses, et Commission de coopération technique en Afrique au sud du Sahara. Des rapports du même genre ont été distribués et présentés par différentes institutions des Nations Unies, à savoir : le Centre des Nations Unies pour le développement des ressources hydrauliques, la FAO, l'OMS et l'OMM. Le rapport présenté par l'Unesco sur l'ensemble des activités entreprises depuis le début de la mise en oeuvre du programme relatif à la zone aride a donné lieu à des débats intéressants, auxquels ont participé dix-huit orateurs exprimant les points de vue de la plupart des régions d'application du Projet majeur et de plusieurs pays d'Amérique latine.

Les orateurs ont rendu hommage aux activités et aux réalisations du programme de la zone aride et notamment au travail accompi par M. Batisse et son équipe. Ils ont été unanimes à déclarer que le programme devait être poursuivi sous une forme appropriée et étendu à d'autres régions.

On a particulièrement mis en relief le fait que des résultats considérables ont été obtenus dans un laps de temps très court et avec des fonds limités.

De nombreuses suggestions ont été faites pour l'avenir, parmi lesquelles il convient de mentionner les suivantes :

1. Intensifier les travaux cartographiques, notamment les levés géomorphologiques.

2. Augmenter beaucoup les moyens permettant de recueillir des données fondamentales et sûres (notamment en ce qui concerne la précipitation) afin que les efforts de recherches puissent se fonder sur des bases solides.

3. Renforcer les études sur l'évapotranspiration, la réduction de l'évaporation, le bilan hydrique et l'érosion continentale.

4. Etendre les travaux sur l'écologie, surtout dans les régions encore peu marquées par l'homme, comme la frange méridionale du Sahara, et étudier les effets écologiques de l'utilisation des terres dans leurs rapports avec l'aridité.

5. Continuer à aider et à encourager les Comités nationaux.

6. A guide book for the practical application of new knowledge should be prepared. The newsletter which was highly commended could include abstracts of significant results obtained.

6. Rédiger un manuel sur l'applicatio pratique des connaissances nouvelles. I publication «Zone aride, Nouvelles du Proj majeur de l'Unesco», très appréciée, pourra comprendre des analyses des résultats im portants déjà obtenus.

PART 3 — SOCIO-ECONOMIC PROBLEMS OF DEVELOPMENT

I. Nomadism in relation to grazing resources, reports by Professor R.E. CAPOT-REY, Dr. MOHAMMED AWAD, Dr. F. BARTH, Dr. R.O. WHYTE.
Chairman: Professor HASSAN AWAD, Rapporteur: Dr. ABDUL HAFIZ.

II. Alternative uses of limited water supplies, reports by Dr. L. LEOPOLD, Mr. G. DROUHIN, Dr. YOUSSEF SIMAIKA, Proffessor A.N. ASKOCHENSKY, Professor G. WHITE.
Chairman: Professor A.H. BEHNIA, Rapporteur: Dr. LUNA B. LEOPOLD.

III. Public awarenes and the educational problem, reports by Dr. A.G. ASGHAR, Professor D. WEINTRAUB, M.J. PETIT and Dr. Z. BEHRAVESH (provisional report).
Chairman: M.A. BAYOUMI, Rapporteur, Professor E.S. HILLS.

TROISIEME PARTIE - PROBLEMES SOCIO-ECO NOMIQUES DE DEVELOPPEMENT

I. Le nomadisme dans ses rapports avec ressources pastorales : rapports de MM R.E. CAPOTREY, MOHAMMED AWAD, BARTH et R.O. WHYTE
Président : M. HASSAN AWAD; Rappo teur : M. ABDUL HAFIZ

II. Diverses utilisations possibles de re sources en eau limitées : rapports MM. L. LEOPOLD, G. DROUHIN, YOUSS SIMAIKA, A.N. ASKOCHENSKY et G. WHI
Président : M. A. H. BEHNIA ; LUNA B. LEOPOLD

III. L'attitude de la population et le problème de l'éducation, rapports de MM. A. ASGHAR, D. WEINTRAUB, J. PETIT et BEHRAVESH (rapport provisoire)
Président : M. A. BAYOUMI; Rappo teur : M. E.S. HILLS

PART 4 — FUTURE OF ARID ZONE RESEARCH

The future of national and international action for arid zone research.
Chairman: Mr. P. PIGANIOL, Rapporteur: Dr. F. DIXEY.

Speakers were unanimous in calling for a continuation of arid zone research under Unesco's leadership, and in expressing satisfaction with what had been achieved so far. Many thought that every effort should be made to increase rather than reduce the funds available and to maintain the programme with a higher level of activity extended to the whole world.

QUATRIEME PARTIE - L'AVENIR DES RECHE CHES SUR LA ZONE ARIDE

Perspectives d'avenir en matière recherches sur la zone aride : action nation et internationale.
President : M. P. PIGANIOL; Rapporteu M. F. DIXEY

Les orateurs ont été unanimes à dem der la poursuite des recherches sur la zo aride sous la direction de l'Unesco, et à primer leur satisfaction devant les résult obtenus jusqu'ici. Beaucoup ont déclaré q fallait s'efforcer d'augmenter plutôt que réduire les fonds disponibles, et de poursui le programme en élevant le niveau des activ et en l'étendant au monde entier.

PUBLICATIONS DE L'A. I. H. S.

encore disponibles

I. COMPTES-RENDUS ET RAPPORTS

Publ. n° 3 — 1926 — Notes et communications	50	F Belges
Publ. n° 6 — Rapports sur l'état de l'hydrologie	25	»
Publ. n° 7 — Id.	25	»
Publ. n° 8 — Id.	25	»
Publ. n° 9 — 1927 — Note et communications	50	»
Publ. n° 13 — 1930 — Réunion du Comité Exécutif	25	»
Publ. n° 14 — 1930 — Commission des Glaciers	25	»
Publ. n° 15 — 1930 — Rapports italiens : Stockholm	50	»
Publ. n° 17 — 1931 — Communications à Stockholm	50	»
Publ. n° 18 — 1930 — Réunion de Stockholm	25	»
Publ. n° 19 — 1931 — Etudes diverses	75	»
Publ. n° 21 — 1934 — Réunion de Lisbonne	50	»
Publ. n° 23 — 1937 — Réunion d'Edimbourg (Neiges et Glaces)	300	»

Assemblée d'Oslo 1948

Publ. n° 28 — Résumé des rapports		25	»
Publ. n° 29 — Tome I — Potamologie et Limnologie		200	»
Publ. n° 30 — Tome II — Neiges et Glaces		200	»
Publ. n° 31 — Tome III — Eaux Souterraines		200	»
Les 4 tomes ensemble	550		»

Assemblée de Bruxelles 1951

Publ. n° 32 — Tome I — Neiges et Glaces		300	»
Publ. n° 33 — Tome II — Eaux Souterraines et Erosion		250	»
Publ. n° 34 — Tome III — Eaux de Surface		350	»
Publ. n° 35 — Tome IV — Symposia sur Zones Arides et crues		125	»
Les 4 tomes ensemble	900		

Assemblée de Rome 1954

Publ. n° 36 — Tome I — Erosion du Sol, Précipitations, etc.		300	»
Publ. n° 37 — Tome II — Eaux Souterraines		450	»
Publ. n° 38 — Tome III — Eaux de surface		425	»
Publ. n° 39 — Tome IV — Neiges et Glaces		375	»
Les 4 tomes ensemble	1350		»

Symposia Darcy — Dijon 1956

Publ. n° 40 — Evaporation		100	»
Publ. n° 41 — Eaux souterraines		250	»
Publ. n° 42 — Crues		300	»
Les 3 tomes ensemble	550		»

Assemblée de Toronto 1957

Publ. n° 43 — Erosion du sol — Précipitation	300	»
Publ. n° 44 — Eaux souterraines — Infl. Végétation — Rosée	300	»
Publ. n° 45 — Eaux de surface — Evaporation	300	»
Publ. n° 46 — Neiges et Glaces	300	»
Les 4 tomes ensemble	1100	»
Publ. n° 47 — Symposium de Chamonix, Physique du mouvement de la glace	300	»
Pulb. n° 48 — Symp. Hannoversch Münden. Eau et Forets	300	»
Publ. n° 49 — Symp. Hannoversch Münden. Lysimètres	150	»
Publ. n° 50 — Légende des cartes hydrogéologiques du Marve	.50	

Assemblée de Helsinki 1960

Publ. n° 51 — Eaux de surface	350	
Publ. n° 52 — Eaux souterraines	350	»
Publ. n° 53 — Erosion continentale, Précipitation, Evaporation sous presse	id.	»
Publ. n° 54 — Neiges et Glaces	id.	»

II. BIBLIOGRAPHIE HYDROLOGIQUE

1934 (Egypte, France, Indes, Italie, Lettonie, Maroc, Pays Baltes, Roumanie, Suède, Suisse, Tchécoslovaquie, Tunisie, Pologne — en 1 vol. 100 F Belges

Argentine

début à 1954 — 25 FB.

Allemagne

1936	—	25 FB.
1937	—	20 FB.
1945-1949	—	30 FB.
1950	—	30 FB.
1951	—	35 FB.
1952	—	35 FB.
1953	—	35 FB.
1954	—	35 FB.
1955	—	40 FB.

Egypte

début à 1954 — 10 FB.

Etats-Unis (+ Canada)

1936	—	30 FB.
1937	—	30 FB.
1938	—	30 FB.
1939	—	30 FB.
1940	—	30 FB.
1941-1950	—	100 FB.
1951-1954	—	60 FB

Pays-Bas

1934	—	20 FB.
1935-1936	—	35 FB.
1937	—	20 FB.
1938-1947	—	30 FB.

Portugal

1924-1954 — 40 FB.

Afrique du Sud

1940-1950 — 25 FB.

Autriche

1934	—	10 FB.
1935	—	10 FB.
1936	—	10 FB.
1945-1955	—	30 FB.

Bulgarie

1935	—	10 FB.
1936	—	10 FB.
1937	—	10 FB.

Espagne

1940-1950	—	25 FB.
1951-1952	—	10 FB.

Japon

1935	—	20 FB.
1936	—	10 FB.

Maroc

1935-1936 — 10 FB.

Pologne

1935	—	20 FB.
1936	—	25 FB.
1937	—	20 FB.
1938	—	20 FB.
1945-1948	—	35 FB.
1949	—	30 FB.
1950	—	30 FB,
1951	—	30 FB.
1952	va paraître	
1953	—	30 FB.
1954	—	30 FB.
1955	—	30 FB.
1955	—	30 FB.
1956	—	35 FB.
1957	—	35 FB.

Australie

1937 — 10 FB.

Italie

1935-1936 — 20 FB.
1937-1953 — 30 FB.

Lithuanie

1935-1938 — 40 FB.

Danemark

1937-1947 — 20 FB.

Esthonie

1936-1938 — 25 FB.

Grande-Bretagne

1936-1937 — 20 FB.

Indes

1936-1952 — 60 FB.

Irlande

1934-1949 — 10 FB.

Lettonie

1934-1938 — 30 FB.

URSS

1954-1957 — 35 FB.
1957-1960 — 35 FB. } en russe.

France

1935-1936 — 25 FB.
1937 — 15 FB.
1938 — 15 FB.
1946-1951 — 20 FB.
1952 — 20 FB.
1953-1955 — 30 FB.

Norvège

1940-1950 — 20 FB.

Suède

1935-1936 — 10 FB.
1937 — 10 FB.
1939-1947 — 20 FB.
1948-1952 — 15 FB.

Suisse

1939-1947 — 30 FB.
1948-1952 — 30 FB.
1952-1954 — 30 FB.

Finlande

jusque 1959 — 35 FB.

Canada

jusque 1958 — 30 FB.

Belgique

1935 — 10 FB.
1936 — 10 FB.
1937 — 20 FB.
1938-1947 — 40 FB.
1948-1952 — 30 FB.
1952-1957 va paraître

Tchécoslovaquie

1935 — 25 FB.
1936 — 25 FB.
1937 — 25 FB.
1938 — 40 FB.
1939 — 35 FB.
1940 — 35 FB.
1941 — 30 FB.
1942 — 35 FB.
1956 — 40 FB.
1957 — 40 FB.

Yougoslavie

du début à 1954-20 FB.

Hongrie

1945-1954 — 50 FB.

Israël

1945-1949 — 20 FB.
1949-1955 — 25 FB.

III. BULLETIN DE L'ASSOCIATION D'HYDROLOGIE

Ce bulletin paraît quatre fois l'an depuis 1956. Il comprend une partie réservée à l'information et une partie scientifique.

Prix de l'abonnement : 250 FB.

IV. PUBLICATIONS DIVERSES

1.	Quelques études présentées à Washington 1939	50 F Belges
2.	Etudes présentées à la Conférence de la Table Ronde sur la possibilité d'utilisation des laboratoires d'hydraulique pour les recherches hydrologiques	75 »
3.	Crues de 1954 — 1 publ. autrichienne	40 »
4.	Rapports de l'Inde au Symposia Darcy à Dijon	50 »
5.	Classification décimale hydrologique en Pologne	25 »

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